The Effects of the Use of Light Weight Pucks on Skill Performance in Women's Hockey

By

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THE EFFECTS OF THE USE OF LIGHT WEIGHT PUCKS ON SKILL PERFORMANCE IN WOMEN'S HOCKEY

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A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirement of the degree of MASTER OF SCIENCE

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ABSTRACT

Ice hockey is one of the most popular sports in Canada and has witnessed a large influx of female participants over the last ten years. More female players are competing in ice hockey and are joining the sport at all ages. Concerns with women's hockey are that the majority of the game is played "on the ice" and many of the shots taken are wrist shots from in close to the goalie. The goal of the Canadian Hockey Association is to increase the velocity of the shots of female players and make it easier to raise the puck off the ice. The present study investigated the effects of the use of light weight pucks on women's hockey using four pucks of different weights (4.5 oz, 5.0 oz, 5.5 oz, and the regulation 6.0 oz puck). The purpose of the study was to determine the effects of light weight pucks on the biomechanics of the wrist shot, as well as, the puck velocity and accuracy of the wrist shot among elite female hockey players. A subproblem was to determine if any difference exists in the stickhandling, passing and goaltending skills of elite developmental female players when using a lighter puck. An additional subproblem was to gather pre and post attitudinal data of elite female players to see if there is a difference in opinion on adopting a lighter puck between age groups and if the players supported its adoption. Three different tools were used to analyze the effects of light weight pucks on the women's game including; 3 dimensional film analysis of the wrist shot, a battery of five hockey skill tests and attitudinal data collected from pre and post test surveys. Twelve subjects from the Canadian National Women's Team (NWT) and 25 subjects from the Canadian National Under 22 Team (U22) participated in the study. Results suggested that there was no significant difference in the kinematic variables of the wrist shot between pucks of four different weights. There was no significant difference in puck velocity between the four puck weights. The passing skill test was the only skill test that yielded significant results with the four puck weights. Passing times for the 4.5 oz puck were significantly slower than the passing results of the 5.0 oz, 5.5 oz and 6.0 oz pucks. Survey results suggested that there was a difference in opinion between the NWT and the U22 in regards to the effects of a light weight puck on women's hockey. Finally, the survey data also revealed that the adoption of a light weight puck into women's hockey was not favored by the NWT or the U22 team.

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This thesis, nor much of my university education, would not have been possible without the support of my family. Mom, Dad, Pam, Bryan and Carter were always there to put a smile on my face when I needed it most and were so patient and flexible with my busy schedule. I have always appreciated each and everyone of them for that and thank them from the bottom of my heart.

To Michelle, I honestly don't know how she put up with my busy schedule over these past couple of years. Her patience and support meant more to me than I ever let her know. I thank her for being there when I wasn't, I will always be grateful.

DEDICATION

I would like to dedicate this thesis to my mom, Judy Leiter. On the day I was to begin the master's program my mom underwent brain surgery. Her strength and courage on that day and every day since then, have always inspired me to pursue goals I never thought possible. More importantly, my mom has taught me to make the most out of each day and appreciate everything I am blessed with, no matter how big or small. The spirit in her eyes and her beautiful smile remind me of how precious life is and how blessed I am to have a mother like her.

Thank you mom for always being there for me and most of all, for just being you.

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CHAPTER 1

INTRODUCTION

Ice hockey is one of the most popular sports in Canada and is often referred to by Canadians as "their game". Many Canadians and especially those involved in the hockey community believe that there has been a decrease in enrollment in youth hockey over the past few years. Hockey is an expensive sport and the costs of equipment and registration can be very high, depending on the level of hockey the child is playing. Despite the economic commitment, and contrary to popular belief, enrollment in amateur hockey has increased in the past decade while soccer and swimming have experienced a decrease in enrollment. From 1991 to 1996, there was a 23% increase in the number of male players registered in Canada (Canadian Amateur Hockey Association, 1995/1996). However, this was not the most significant increase in participation during that six-year period. The number of female participants registered with the Canadian Amateur Hockey Association (CAHA) increased by 200%. In 1996, the total number of players sanctioned by the CAHA reached 507,000 with female players making up 5% of that population.

Many studies have looked at the attrition rates and motives of male and female sport participants. The majority of these studies are survey based (Burton, 1988; Gould, 1987; Gould and Horn, 1984; Robinson and Carron, 1982) and explore reasons for why players may continue in a sport or drop out. Six major reasons for playing youth sports, listed in order of importance are; fun, improving and learning new skills, affiliation with other players, fitness, competition and energy release (Gill, Gross, and Huddleston, 1983, Gould, Feltz and Weiss, 1985; Gould and Horn, 1984; Weiss, 1993). Studies by Burton (1988), Gould (1987), Gould and Horn (1984) and Robinson and Carron (1982) also reveal the problems that cause children to leave a sport such as lack of playing time, inadequate instruction, competitive stress, lack of peer-parental support, etc. In order to increase or maintain enrollment, parents, coaches and fans must focus on the positive aspects of the game that keep children coming back to the rink. Improving on old skills and learning new ones are aspects that parents and coaches should pay more attention to. Children want to learn and get better, practice breeds success. Lack of development often leads to frustration that may eventually cause a player to leave the sport.

Boyd, Trudel and Donohue (1997) cite studies that report that the enjoyment of the athletes, male and female, is dependent on the proficiency and rate of acquisition of various skills. In regards to women's hockey, an influx of ringette players has resulted in a rapid increase in players at all age levels compared to male hockey in which the majority of new players are in the youth categories. This results in a vast range of skill level in each age group, especially in the areas of puckhandling and shooting. Many of the participants who played ringette in the past can skate at a high skill level. However, the shooting and handling of a ring are much different than with a puck and some female players experience frustration when playing with the unfamiliar black disc.

In addition to having female participants join the sport at a later age or different developmental level, the puck was designed many years ago with the intention of being used by male players. "It has been suggested that skill performance by women may be limited in those sports which do not have modified equipment designed specifically for their use (Eason, 1965; Pitts, 1985). The differences in performance may be attributed to the contrasts in height, weight, hand size and upper body strength between males and females in sports employing the same equipment (Eason, 1978; Husak, 1984; Dailey and Harris, 1984; Critelli, 1984; and Pitts, 1985). "Males are, on average, 10 cm taller and kg heavier than the average female; males are 30 percent stronger in the lower body and up to 50 percent stronger in the upper body than females; males have faster movement time and reaction time; males have only one-third to one-half of the percent body fat of females; males have wider shoulders and a higher center of gravity than females" (Alexander, 2001, p. A9). Males may not be more skilled than females but there bodies are not comparable and either are the sports they participate in. "The female shot put (eight pounds, nine ounces) weighs just over one half as much as the male shot put (16lb); and no one would even consider having them compete together or try to use the same implement" (Alexander, 2001, p. A9) Equipment modification is not only useful for gender differences but for any strength and size differences between players. A report by Strean (1999) suggested that a 50 kg (80 lb) child using a regulation 234.4 g (6.0oz) puck is equivalent to a 94 kg (150 lb) player using a 312.5g (11 oz) puck. He also stated that attempting to learn and adopt new skills with equipment that is not designed for a participant's size, weight and strength is counterproductive. One of the greatest players to ever lace up a pair of skates, Wayne Gretzky, agrees with this statement and is quoted as saying "Why does my son, who's nine years old, use the same puck that I use? Why should he have to? It should be a lighter puck". Considering the impact Wayne Gretzky has made on the sport of ice hockey, it is difficult to ignore his suggestions and recommendations.

Fortunately, the sport of ice hockey does not shy away from equipment modifications and adopted a lighter, thinner and more flexible stick for younger players. A study by Dore and Roy (1976) in the mid 1970's analyzed the effects of stick flexibility on shot velocity among various players. As a result of the recommendations and findings of this study, a new stick was designed for the youth of the game. More recently, stick manufacturers have designed sticks for female players that are also lighter, thinner and more flexible. The question is, are more equipment modifications necessary to accommodate the female and youth hockey player?

The Province of Alberta (Strean, 1999) answered yes to this question and adopted a lighter puck for players participating in youth hockey at the Initiation (6-9 years olds) and Novice levels (9-11 year olds). The inaugural season with the puck was a positive one and the puck, which is 2 oz lighter than the conventional 6 oz puck, was helpful for players learning new skills, and increased the confidence of younger participants, especially at lower skill levels (Strean, 1999). The data for the study were collected from 28 coaches in a focus group and from 138 surveys returned by parents.

The results from a focus group for coaches suggested that the 4.0 oz puck was useful for skill development at the Initiation level. The lighter puck improved the players' ability to handle the puck in front of the body while skating, increased confidence among players and made the game more challenging for the goaltenders. The most noticeable difference was the players' ability to raise the puck at a much earlier age. At the Novice level, coaches' reactions were generally positive, especially at the lower skill levels as players demonstrated improved puck skills. However, at the higher skill levels, coaches expressed concern about using the 4 oz puck in a game and reported that the puck bounced too much and players often over skated the puck, especially when the ice was slower near the latter stages of a game. It should be noted that these concerns were not evident at the lower skill levels.

The results of the parental survey at the Initiation level were similar to the sentiments of the coaches. There was a general consensus that kids loved the lighter puck as the players were able to stick handle and raise the 4 oz projectile more easily. Parents also reported that the children learned new skills at a greater rate and improved in other skills that elevated the players' confidence, especially at the lower skill levels. As with the coaches, there was concern regarding the liveliness of the puck as it bounced too much and it stuck to the ice more in the latter stages of a game, when the ice was slow. However, nearly all the parents approved the use of the 4 oz puck at the Initiation level. The parents' reactions at the Novice level were much more diverse and ranged from "absolutely useless waste of time" to "best idea in 20 years". The parents of the older, more experienced and skilled players expressed a more negative attitude towards the use of a light weight puck. Parents were also concerned with the amount of bounce the puck possessed and felt it did not slide as well on the snowy ice, that there were too many shots over the net, and there were increased difficulties in face-off situations. Many parents reported the puck was a good idea for the Initiation level but was not necessary at the Novice level. Parents at both levels agreed that the puck bounced too much and there was concern over the transition to the regulation puck when the children advance to an older age level or when games are played in a province that does not use the lighter puck. It is unfortunate that the players were not surveyed in this study as the players' attitudes towards the use of a light weight puck would have been useful.

As a result of the report, Strean (1999) recommended the use of a heavier, 5 oz puck, at the higher skill levels in the Novice age category and a puck that would be designed to bounce less. The present study included the use of a 5.0 oz puck as well as a 4.5 oz and 5.5 oz puck. This gave the players a chance to try all three weights and note any differences in feel or bounce between weights. Strean (1999) also suggested a more scientific examination of the effects on skill development, which this study attempted to address. In addition to the implementation of the lighter puck at the Initiation level in Alberta, the 4.0 oz puck was used by the U.S.A. National Women's team in an exhibition match in 1999. Although there is no research data available, in general, the attitudes of the players towards the use of a light weight puck in women's hockey were positive. Their interest in the light weight puck along with the youth programs in Alberta mentioned above, are two reasons the present study was initiated.

There are many sports where women use a lighter projectile than men, based on their differences in height, weight and strength. Females use a lighter projectile in all track and field throwing events, as well as in the sport of basketball. The NCAA women's basketball program began using the lighter (2 1/2 oz lighter) and smaller (2.5 cm smaller in circumference) basketball for intercollegiate competition in the 1984-1985 season and used it for interscholastic play in the subsequent year (Husak, Poto, Stein, 1986). The process of adopting a lighter projectile was a lengthy one that lasted two years. Initially, there were concerns over the cost of the basketball, how female basketball would be viewed, and international repercussions that might result from the smaller basketball (Hutchison, 1984). In the end, the selection committee had 12 votes for the smaller basketball and four against. It was suggested to those who opposed the change to "utilize the basketball for one season, critically evaluate the strengths and weaknesses, and prepare your arguments for the next spring" (Hutchinson, 1984, p 21).

Prior to accepting the use of a lighter and smaller basketball in the Canadian Interuniversity Athletic Union (CIAU), a major study was performed by Bedingfield and Skleryk (1985). Three different basketballs were used and subjects included 71 female and 35 male CIAU basketball players. The players performed a battery of basketball skill tests that included passing, dribbling and shooting. It was concluded that passing speed was increased, consistent with the findings of McClements , Bell, Fairlax, Fry and Wilson (1982). Dribbling performance was reduced, and the smaller ball was not found to improve performance in any of the five skill tests. McClements et al. (1982) and Bedingfield and Skleryk (1985) noted that sending skills (i.e. passing and shooting) were performed better with the smaller ball, whereas receiving skills (catching a pass) favored the larger ball. Therefore, the results offset one another. An optimal ball size would be one that had positive effects on both sending and receiving skills. McClements et al. (1982) included similar tests and many of the results were consistent with those of Bedingfield and Skleryk (1985). Although both studies yielded similar results, Bedingfield and Skleryk (1985) were not in favor of the smaller lighter ball, contrary to McClements (1982). Bedingfield's and Skleryk's (1985) conclusion was that "the ball would not be suitable as an alternative to the larger basketball currently used for CIAU intercollegiate play" (p.39) and until this present day, the smaller ball has not been adopted by the CIAU for intercollegiate play.

The adoption of lighter projectiles is common in youth and minor sport organizations. In fact, "it is difficult to find a sport that does not modify the size of its equipment to match the size and strength of the kids. In soccer, the under 10 category uses a size 3 ball, under 13 uses a size 4 ball and it is not until athletes reach the under 15 category that they use a regulation size 5 ball" (Strean, 1999, p.3).

The major difference in hockey is that the lighter puck is still the same size as the standard puck and may not affect receiving skills as did the smaller basketball. One concern with the lighter puck is the "liveliness" of the object as identified in Strean's (1999) study. It was also discovered with the lighter basketball that shots tended to rim out or bounce off the rim more often because the ball was lighter, cancelling out the effectiveness of longer range shots (Valkenburg, 1985). As with the lighter basketball, several studies must be performed to evaluate the effect of a lighter puck on the performance of female hockey players.

Purpose of the Study

The purpose of this study was to determine the effects of a light weight puck on the biomechanics of the wrist shot, as well as the puck velocity and accuracy of the wrist shot among elite female hockey players. Subpurpose #1 of the study was to determine if any difference exists in the stickhandling, passing, and goaltending skills of elite developmental female players when using a light weight puck. Subpurpose #2 was to gather pre and post attitudinal data of elite female players to see if there is a difference in opinion on adopting a lighter puck between age groups and if the players supported the change.

Null Hypotheses

1) The biomechanics of the wrist shot will not differ when executing a wrist shot using a light weight puck (2) the puck velocity of the shot will not increase. 3) The passing and

shooting skills of the female hockey players will not differ when using the light weight pucks. 4) Attitudinal data will not differ between age groups and the players will not support the adoption of a lighter projectile into the sport of women's hockey.

Rationale for the Study

The use of a light weight puck by females may increase the velocity of the wrist shot and allow the players to raise the puck off the ice at a greater angle and velocity. One concern of women's hockey is that the game is played, for the most part, on the ice and the number of times the puck is raised off the ice is minimal. An increase in the vertical and horizontal velocities of the puck may challenge the goalies to a greater degree and lead to more goals. In addition, the players would pass the puck with a greater velocity and increase the overall speed at which the game is played. It is possible the players will also be more proficient in stickhandling with the lighter puck, further increasing the speed of the game. A lighter puck may result in improved technique and more rapid development of shooting skills, as it did at the Initiation level in Alberta (Strean 1999), narrowing the gap in skill level that currently exists in women's hockey. Acquisition of new skills and the improvement of old ones may increase players' confidence, especially at the lower skill levels. However, with the limited time and resources available for the study, elite players were used for testing as their skill performance is more consistent and any change in skill performance will be more evident from one trial to the next. In addition, many of the developing players look up to the National Team members and value their opinions. The attitudes of the players on the National team may influence those of the developing less experienced players.

"Women's ice hockey is one of the fastest growing sports in Canada" (Boyd et al.1997, p.31). It is important that the current participants and those that join in the future have fun and continue to develop their skills. However, before the light weight puck is implemented at this level, players should be given the opportunity to experience the light weight puck and express their attitudes towards it. It is difficult for players to comment on a concept they have never been exposed to, or to accept a new projectile that they have never tried. Allowing female players to explore the light weight pucks will not only provide investigators with more accurate feelings and attitudes towards the light weight puck, it will provide the athletes with a sense of involvement in the decision to adopt a light weight puck in women's hockey. It will also provide the investigators with objective data on the effects of a light weight puck on skill performance.

Limitations

1. Selection of highly skilled female hockey players limited the number of subjects in the study and decreased the generalizability of the results.

2. Due to time restraints, the players performed some of the skill tests once instead of twice which may have decreased the differences in performance that were witnessed, as even one practice trial usually results in substantial improvement of the skill (Burton and Welch, 1990).

Delimitations

1. All subjects were elite female hockey players from the Canadian National Women's Senior Team and the Canadian National Women's Under 22 Team.

Definition of Terms

Angular displacement: change in angular position (Hall, 1999).

Angular velocity: rate of change of angular position (Hall, 1999)

Angular displacement of the hip: change in the angle formed by drawing a line from the joint center of one hip to the joint center of the other hip and connecting it to the z axis.

Angular displacement of the stick blade: change in the angle formed by drawing a line from the toe of the stick blade to the heal of the stick blade and connecting the heal to a line that represents the x axis.

Angular displacement of the shoulder girdle: change in the angle formed by drawing a line from the joint center of one shoulder to the joint center of the other shoulder and connecting it to the z axis.

Angular velocity of the hip: rate of angular displacement of the hip.

Angular velocity of the stick blade: rate of angular displacement of the stick blade.

Angular velocity of the shoulder: rate of angular displacement of the shoulder girdle.

Coefficient of restitution: index of elasticity for bodies of a collision (Hall, 1999).

Forearm pronation: pronation is the movement of the forearm and hand that rotates the radius medially around the longitudinal axis so that the palm of the hand faces posteriorly (Moore & Dailey, 1999).

Impulse: the product of an applied force and the time over which the force is applied (Hall, 1999).

Momentum: the product of the mass of a body or object and the velocity at which the body or object is travelling (Hall, 1999).

Resultant displacement: displacement of an object in the x, y , and z reference planes.

Resultant velocity: rate of displacement of an object in the x, y, and z planes.

CHAPTER 2

REVIEW OF LITERATURE

The Wrist Shot

There are four basic shots in ice hockey; the wrist or sweep shot, the snap shot, the slap shot and the backhand. The snap, wrist and slap shots are forehand shooting motions, while the backhand, as its name suggests, is a backhand shooting motion (Halliwell, Groppel, & Ward, 1978). For the purposes of this study, the wrist shot was selected over the more difficult and less accurate snap and slap shots. The wrist shot can be performed while the player is stationary or while skating but similar to the study by Dore and Roy (1976), only the stationary wrist shot was studied. This ensured the player remained in the calibrated spatial planes throughout the movement, increasing the accuracy of the video analysis.

Although many youngsters and fans are fascinated with the velocity of the slap shot, several of the legendary Montreal Canadians state that "the wrist shot is a much more accurate shot" and "the key is not to want to shoot the puck through the net or to make the big sound on the boards. It is to combine the speed of executing the shot with precision" (Tremblay, 1977-78, p.18). These words of wisdom continue to be echoed throughout the hockey world by many of its great players. The reason the wrist shot is so accurate is "...it allows the player to feel the puck tight to his stick blade and he can aim the shot at his leisure, and at all times he can look at the target he has selected" (Tremblay, 1977-78, p.18). Despite the accuracy and frequency of use of the wrist shot, little research has been done on this skill. "A limited amount of research has been done on ice hockey. A few studies have subjectively dealt with the mechanics of shooting and passing...." (Naud and Holt, 1975, p.12). Dore and Roy (1976), two of the most prolific hockey researchers, stated that only one study in 1974 by Romanchevsky had dealt with the kinematics and kinetics of ice hockey shots up to that point.

Dore and Roy (1976) did perform a kinematic analysis of hockey shots and reported that the force diagrams of the wrist shot were quite repeatable from one player to another. One possible explanation is the wrist shot is less difficult to perform and is, therefore, quite uniform between players.

> " During the wind up of the stationary wrist shot, the puck is brought backward along the ice and is kept in contact with the blade of the stick throughout the shooting action. The stick is then brought forward rapidly in a sweeping action and is terminated by additional wrist snap, forearm pronation of the bottom hand, forearm supination of the upper hand and follow through to obtain maximum velocity of the shot. The shooter is allowed only one stride forward, which is part of the natural shooting action. The length of the backswing on the windup and the amount of sweep and wrist action varies a great deal among hockey players" (Alexander, Drake, Reichenbach, Haddod, J. 1963, p.259).

The large variation in the backswing, the amount of sweep and the wrist action between players may be due to the strength of the athlete or the time they have to release the shot. It is possible that players that are stronger and release the puck quicker, have an abbreviated backswing and a quicker and more forceful wrist action to accomplish the velocity of their shot. Tony Granato of the San Jose Sharks states that "accuracy is one of the most important things and quick release is another....with the speed of the game and the tremendous goaltending in the N.H.L., quick release is important" (www.exploratorium.edu/hockey/shooting/html). A physicist for exploratorium.com reported "without the wind-up, part of the energy comes from the player pressing down on the stick and then releasing it suddenly (with a flick of the wrists). The stick stores the energy and the wrist movement releases it. How fast a player can make the puck go depends not just the force that the stick exerts on the puck, but the amount of time that the stick is in contact with the puck" (www.exploratorium.edu/hockey/shooting/html). This is consistent with Newton's second law and the relationship between momentum and impulse. Basically, when an impulse acts on a system (the stick on the puck), the momentum of the system (the puck changes) depending on the magnitude of the impulse (Hall, 1999). Impulse (J) is the product of the magnitude of the force (F) and the time over which the force is applied (t). The greater the force and the longer period of time over which the force acts, the greater the impulse. The greater the impulse, the greater the change in momentum or puck velocity of the wrist shot. (Hall, 1999). Therefore, if the players use a longer backswing during the wrist shot and the puck stays in contact with the stick blade longer, the velocity of the puck will be greater than if the player used a shorter backswing but applied the same force.

Additionally, a study by Halliwell et al. (1978) investigated the motion of the top and bottom hand of professional players executing a wrist shot. The authors discovered that the pattern of the hands differed between a high and a low shot. Although the pattern of the hands, the amount of wrist action, and the length of the backswing may differ between players, the biomechanics of the forward sweeping action of the player are very similar within and between players (Dore and Roy, 1976).

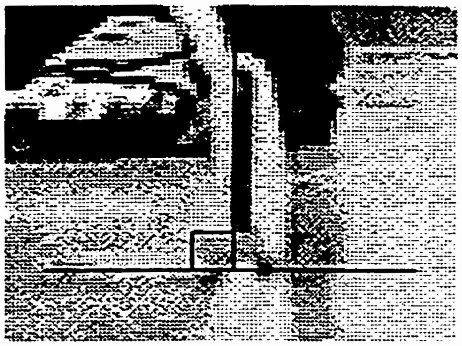
As in many other skills in sports, the wrist shot can be broken down into its component parts for analysis. For ease of analysis, a skill can be broken down into the following 5 parts:

1) Preparatory movements – the movements the athlete performs to get ready for the skill such as footwork or body position.
2) Backswing – the movements made just prior to the force-producing movements in a skill.
3) Force producing movements – these include all body movements which are executed to produce force for impact or propulsion.
4) Critical instant – the point in the skill which determines the effectiveness of the skill, and includes release of an implement, impact with a ball etc.
5) Follow-through – the body movements that occur following the critical instant, and occur primarily to decelerate body parts to prevent injury. (Alexander, 1999).

These five components of the wrist shot will each be discussed in detail below.

Preparatory movements

During the preparatory movements of the wrist shot (Figure 2-1a) the feet are placed shoulder width apart and the knees are slightly bent (Hayward, 1978). The left-right axis through the shoulders, hips, knees and ankles are perpendicular to the cross bar. The top hand on the stick is placed at the butt of the stick in a shake hands position. The lower hand is placed on the stick about shoulder width distance from the top hand. The thenar and hypothenar eminences (fleshy part of the hand) are placed behind the shaft of the stick to allow for the greatest force to be applied. For the stationary wrist shot, the puck is placed in the middle of the long axis of the feet, about 50 cm anterior to the horizontal line connecting the toe of one skate blade to the toe of the other blade. The blade of the stick is in a neutral (vertical) position (Figure 2-1b). Head is slightly flexed and eyes are on the puck to ensure it is positioned near the middle or the heel of the stick blade.



(a) **(b)**

Figure 2-1 (a) Frontal view of the preparatory movements of the wrist shot. (b) Frontal view of the stick blade in a neutral position.

Backswing movements

As the player executes the backswing movements of the skill (Figure 2-2) the blade of the stick is placed anterior to (in front of) the puck and is tilted posteriorly, backwards, (Figure 2-3) with the puck between the heel and the middle of the blade (Hayward, 1978).

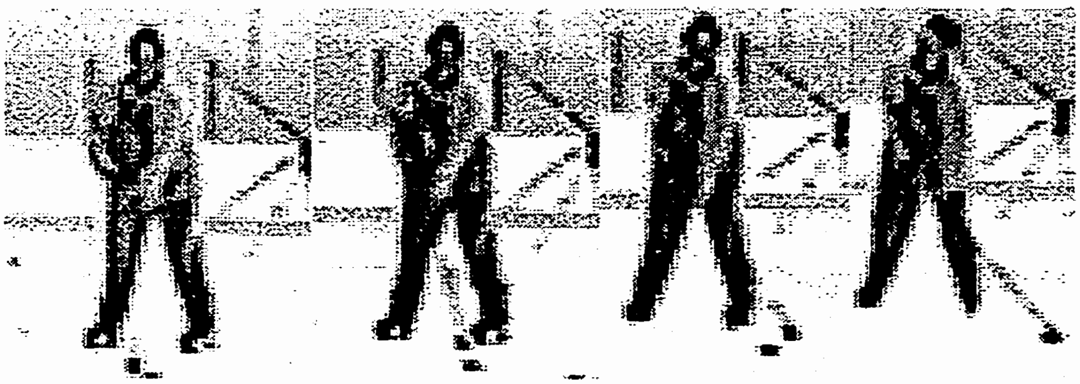


Figure 2-2 Frontal view of the backswing movements of the wrist shot.

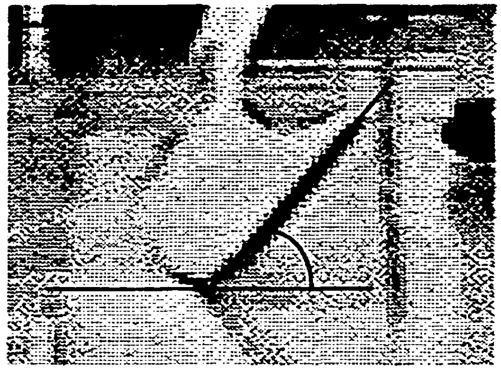
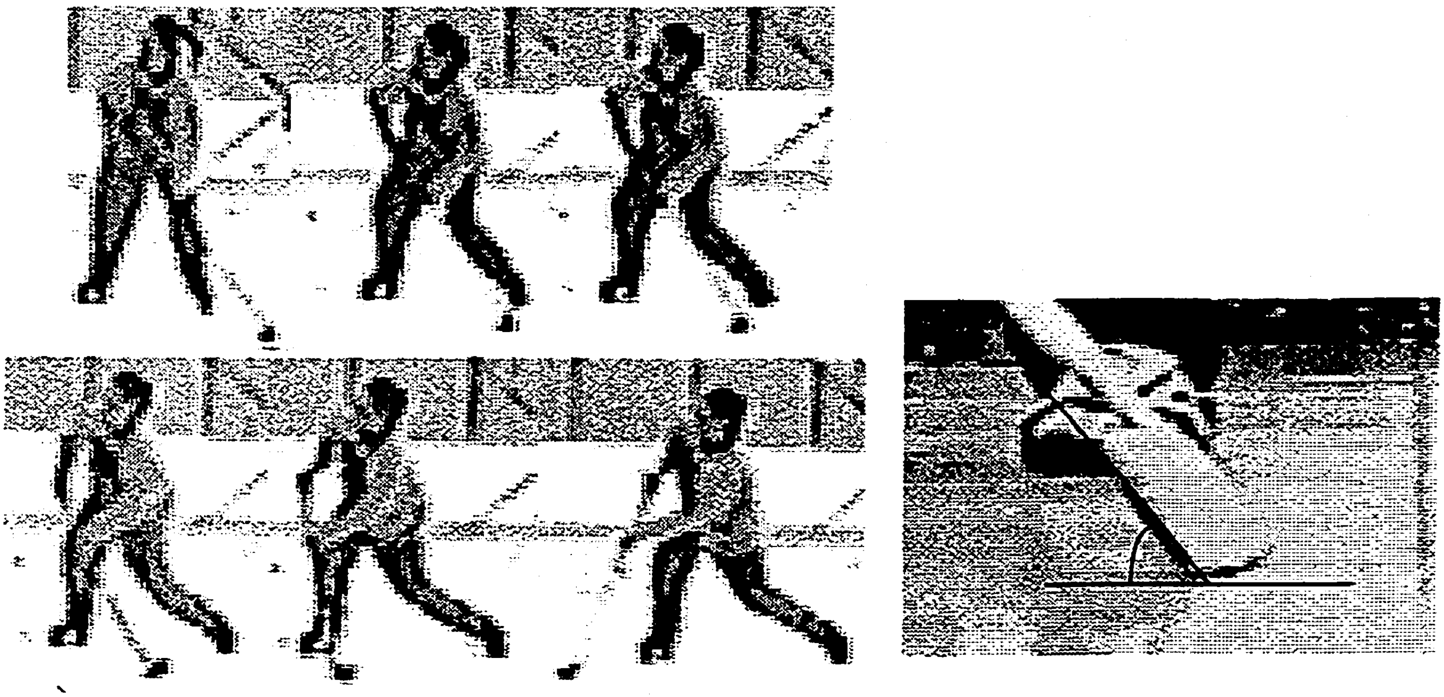


Figure 2-3 Sagittal view of the stick blade in a posterior tilt position.

This is achieved by supinating the bottom hand on the stick and pronating the top hand to angle the blade of the stick posteriorly from its neutral position, this action prevents the puck from sliding off the stick. The puck is kept in contact with the blade throughout the backswing movements (Alexander et al., 1963). The top arm on the stick begins to horizontally adduct in the frontal plane (move across the body) as the bottom arm horizontally abducts (moves away from the body) in the same plane to sweep the puck laterally backward to the foot furthest from the goal. Hayward (1978) states that the puck should be placed about 30 cm behind the player's rear foot. During this motion the weight is transferred from the front foot (foot closest to the goal) to the back foot by plantarflexing (top of the foot moves away from the lower leg) the ankle and extending the knee and hip joints of the front leg. In the contralateral (opposite) leg, dorsiflexion (top of the foot moves closer to the lower leg) of the ankle and deeper flexion of the hip and knee occur to accommodate the weight shift. This weight transfer loads the back leg and puts the plantarflexors, knee extensors, and hip extensors on a stretch. If done quickly, the stretching evokes the stretch reflex enhancing voluntary muscle contraction and increasing the power of the movement (Fleisig, Barrentine, Escamilla, & Andrews, 1996). The trunk is rotated about the long axis of the body away from the goal and is in slight flexion.

Force producing movements

The force producing movements (Figure 2-4a) begin when the backswing ends. It is critical to begin the force producing movements immediately after the muscles of the back leg have been put on a stretch to initiate the stretch reflex. As the plantarflexors, knee and hip extensors contract, the weight is shifted to the front leg and the stick begins to move forward in a rapid sweeping action with the blade tilted over the puck in a forward tilt position (Figure 2-4b).



(a) (b)

Figure 2-4 (a) Sagittal view of the force producing movements of the wrist shot. (b) Sagittal view of the stick blade in an anterior tilt position.

This decreases the likelihood that the puck will slide off the blade and is accomplished by pronating the lower hand and supinating the top hand. "The front leg is critical at this point as it must be rigid with the skates parallel to the direction of the shot to allow the hips to "get through" and stabilizes the player for a body check" (Hayes, 1965, p.31). This allows for increased hip rotation and more power to be generated from the push off of the back leg (Hayward, 1978). Hip rotation is followed by rotation of the trunk about the longitudinal axis of the body as the elbow of the top hand is held close to the body to decrease the radius of rotation and increase the velocity of the stick (Hayes, 1965). The greater the radius of rotation of the upper body about the longitudinal axis of the trunk, the greater the inertia, or resistance to rotation, of the trunk and the slower the movement ($I=mk^2$), where I represents inertia, m is the mass of the stick and upper limbs, and k^2 is the radius of gyration. The weight of the stick and upper limbs remains constant, therefore, any increase in the radius of gyration results in an increase in inertia, or the resistance of a body to rotate (Hall, 1999). The arm of the bottom hand remains straight to transfer the power from the weight shift and rotation of the hips, trunk and finally the shoulders to the shaft of the stick (Hayward, 1978).

During the forward sweep of the stick, the upper hand is ahead of the lower hand and places the blade and the shaft of the stick at an acute angle to the vertical. As the stick comes through, the blade and the shaft gradually lose the forward tilt and become near vertical as the stick passes the front leg. Just prior to critical instant or release of the puck, the top hand rapidly reverses its forward movement and moves away from the target and towards the body as the lower hand continues to the target. The shaft of the stick acts as a first class lever as the top hand reverses its direction and the bottom hand becomes the fulcrum. However, it can also be thought of as a third class lever because the bottom hand is continuously moving and the top hand's displacement is minimal. In either case, the puck is the resistance (Hall, 1999). It is possible that the more the player takes advantage of the first class lever, the greater the height of the shot as the lever projects the blade of the stick rapidly in the vertical direction. Whether the player is executing a high or low shot, it appears the stick serves as both a 1st and 3rd class lever throughout the movement. The head should be rotated towards the target and the eyes should be looking for an opening on the goaltender throughout this movement.

Critical instant

Critical instant (Figure 2-5) is the point at which the puck is released from the blade of the stick during the wrist shot. It is the point during the wrist shot that determines the angle and velocity of release as well as the direction of the shot. By tilting the blade of the stick anteriorly, or posteriorly, or rotating the blade about the longitudinal axis of the stick in a clockwise or counterclockwise direction, the puck can be aimed towards the target. In addition, it appears this is the point in the shot where the bottom hand is rapidly pronated as the top hand supinates about the forearm axis. As the wrist uncocks and snaps into this position, power is added to the shot. It is from this movement that the shot was given its name (Hayward, 1978). The power (P) of this shot ($P=W/T$) is dependent on the force of the wrist action multiplied by the distance over which it occurs divided by the time over which the force is applied (Hall, 1999). In this equation, W is equal to work or force * distance and t is equal to time. The goal of the wrist shot is to move the stick through the greatest distance with the most force possible in a very short interval of time to achieve maximal power of the shot.

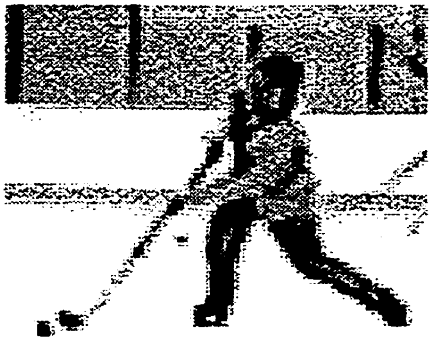


Figure 2-5 Frontal view of the critical instant phase of the wrist shot.

Follow through movements

Immediately after the critical instant, the follow through movements (Figure 2-6) of the wrist shot are executed. During this phase of the skill there should be a complete follow through of the arms, body and legs as the eyes continue to focus on the target (Hayward, 1978). The follow through should occur over the greatest distance and time possible to slow down the body and prevent injury. An impulse (J) is needed to stop the momentum (mv, where m = mass and v = velocity) of the arms and stick and because the momentum of the arms and stick are so large, a great impulse is required. Impulse is equal to the change in momentum of a body ($mv_i - mv_f$) and can be broken down into force multiplied by time. Therefore, if it is possible to slow down the body over a greater period of time, the chance of injury is reduced. To slow down the momentum of the body, there is dorsiflexion of the ankle, knee and hip flexion in the front leg, an eccentric contraction of the trunk rotators on the left side of the body to decrease trunk rotation, and contraction of the arm extensors, horizontal abductors and supinators of the left arm to slow down the velocity of the upper limb. During this phase, the hips, trunk and shoulders complete the action of rotation. Flexion and horizontal adduction of the left shoulder are stopped along with pronation of the left forearm.

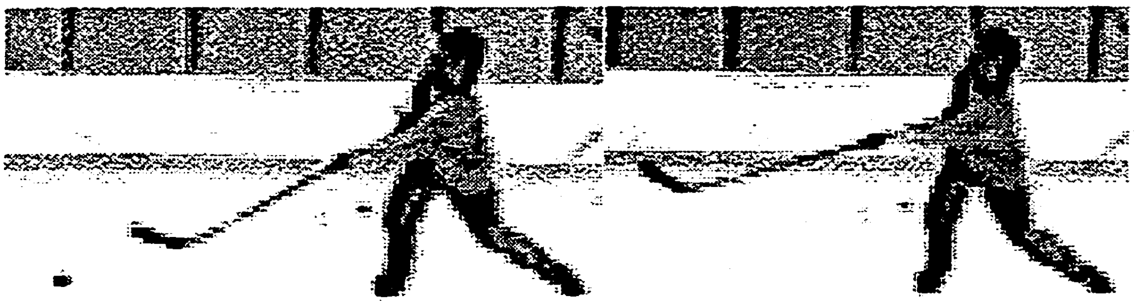


Figure 2-6 Frontal view of the follow through movements of the wrist shot.

Pucks

The purpose of this study was to analyze the effects of a light weight puck on women's hockey. Therefore, three lighter weight pucks were produced giving four different pucks to be used for testing, differing in weight but not size. The standard or regulation puck is 6 oz (170.1g) in weight, 7.5 cm in radius and a height of 2.5 cm. The three test pucks were manufactured by Viceroy Rubbers and Plastics Limited (Toronto, Ontario). All of the test pucks were color coded on one side of the puck and labeled with the Canadian Hockey logo and weight of the puck. The lightest puck was 4.5 oz (127.58 g) and had a yellow label on the one side, the blue puck was 5.0 oz (141.75 g) in weight and the heaviest puck of the test pucks was red in color with a weight of 5.5 oz or 155.93g. The pucks increased in weight in 0.5 oz (14.18 g) increments. It was reported in the study by Strean (1999) that the lighter, less dense pucks were "livelier" than the regulation pucks, however, the coefficient of restitution of the pucks has not been tested.

Video Analysis

This study used video analysis to investigate the biomechanics of the wrist shot and determine if a player's technique changed when a lighter puck was shot. Video analysis was also utilized to calculate the velocity of the puck as it is more accurate than a radar gun, often used to determine the velocity of a puck or baseball.

Many scientists and researchers use film and video analysis to study a particular skill or movement pattern of an athlete. Many of the sports movements occur at such a high velocity it is impractical to use the human eye to observe components of the skill. Video and film tape allow the observer to view the film one frame at a time and break the skill into its various components.

In the past few years there has been a trend to replace cinematography or film with video for the purpose of analysis in the field of biomechanics (Angulo and Dapena, 1992). There are several advantages to using video, some of which include: low cost of videotapes, the images are immediately available for analysis, filming procedures can be adjusted on site immediately after viewing the film and errors in exposure are less likely. Unfortunately, video film does have its disadvantages: the overall quality of the tape is inferior to film, decreasing the accuracy of data obtained by manual digitization. "Previous studies have shown data obtained from video images to be of lower accuracy than those derived from cinefilm" (Shapiro, Blow and Rash, 1987; Kennedy, Wright & Smith, 1989; Angulo and Dapena, 1992). The inferiority of the video image is mainly due to image quality and 'pixel (the minute divisions that compose a video image) size'. Video image is affected by variables such as lens quality, video recording format, image capture board and video monitor resolution. The greatest errors seem to be attributed to lens distortion, overall poor image quality and low measurement resolution. Pixel size in video film is smaller than cinefilm and decreases the accuracy of digitization (Kerwin and Twigg, 1998).

One other major drawback of the video is the speed at which the movement is filmed. High speed film captures 200 frames per second or greater. Standard video taping can record at 30 frames per second which can be further enhanced by video analysis software to 60 frames per second (Peak Performance Technologies, 1994). However, 60 frames per second is acceptable for the analysis of most sports skills and "improving lens quality and image recording format by using a superior camera/lens combination and higher resolution of video tape produced a 45% improvement in accuracy" (Kerwin and Twigg, 1998, p.182). Three previous studies (Alexander et al., 1963; Halliwell et al., 1978; Naud and Holt, 1975) investigating the kinematics of hockey shots used cinematographic analysis, and there are no studies in the literature that have used video tape. However, the three studies mentioned above were performed before video tape analysis was widely used.

Data Smoothing

A technique commonly used in video analysis is data smoothing to filter out inaccuracies caused by human error or lack of technical precision.

The Peak V Video Analysis system contains a Data Conditioner program that allows the user to filter the paths of each data point of the spatial model in all three dimensions. A digital filter is used to filter out random amplitude noise that is introduced when digitizing a video tape. The Peak V Video Analysis system digitizes pictures at a constant rate of 60 Hz, therefore, the error resulting from digitizing occurs at a constant frequency but with varying levels of amplitude. The more a filter is passed over each data point the less amplitude or noise in the data. Filtering will eliminate unrealistic values obtained during calculation of the kinetics of velocities, accelerations etc. For example, if a point is digitized inaccurately, it could result in a very large or small velocity as compared to the other data points. The filter attempts to smooth out these inaccuracies and provide data curves that are more consistent. However, it is important not to filter the data too much as valuable peak velocities or accelerations may be reduced.

Most sports skills include a point at which the athlete or a body segment of the athlete reaches a peak value that is critical to performance. Excessive smoothing of this data may underestimate the velocity or acceleration at which the movement is occurring. The Peak system employs three different types of filters, The Butterworth Filter, The Fast Fourier Transform (FTT) filter and the Cubic Spline filter. The Butterworth Filter is most valuable as an all-purpose filter to filter out the constant error resulting from digitization of the videotape. The FTT filter is used to filter out random noise rather than constant noise, and is used most often when the skill is cyclic in nature (eg. cyclist). The best filter for movement that is parabolic in nature, such as swinging a baseball bat or golf club etc. is the Cubic Spline algorithm with a knot at every data point (Peak Performance Technologies, 1994). The extent to which the data is smoothed are dependent on the number of passes that are made with the filter. More passes means smoother data, however, if too many passes are used there is a risk of losing important peaks and valleys in the data that may be valuable to the coach and athlete when analyzing the movement. Generally, about 2-4 passes are optimal for smoothing the data and maintaining the maximum and minimum values of each data point within a skill.

Skill Tests

When investigating the implications of a lighter puck on the sport of women's ice hockey it is important to study as many components of the game as possible. The hockey skill tests were incorporated to determine the effects a lighter puck has on a player's passing, puckhandling and shooting skills, as well as, the goalie's ability to save the puck.

Many of the studies reported in the 1980's to determine if women's basketball should adopt a smaller and lighter ball included a battery of skills tests. The majority of these tests were adopted and adapted from the American Association of Health, Physical Education and Recreation AAPHER Basketball Skills Test Manual for Girls (1966). In fact, Bedingfield & Skleryk (1985) used tests very similar to Husak's study in 1984 and stated that a study by Dailey and Harris (1984) also used these tests. Skill tests were used to measure players' performance in skills such as the lay-up, shooting, passing and dribbling. In both studies the players used the regulation ball and the smaller, lighter women's ball to determine if differences existed between players' performance with each of the basketballs. The skills tests were also included by Husak et al. (1984) for the players' benefit and gave the participants a chance to experience the smaller and lighter ball before the questionnaire was filled out. The players' responses were more valid after the tests as many of the questions referred to performance of skills with the lighter ball and the athletes' attitudes towards adopting a new ball into the sport of women's basketball.

Unfortunately, most of the skill tests in ice hockey do not measure a player's performance with the puck; rather the tests evaluate the skating ability of the participant. Bosco and Gustafson (1983) state that ice hockey skill tests are nearly nonexistent in the research literature (Bosco & Gustafson, 1983). A report by Hansen, Hunter, Mahoney & Moore (1970) provided an evaluation of tests often used to assess the ability of a hockey player. Three of these tests were used and adapted for the current study. The first test, previously used in a study by Merrifield and Walford (1969), was performed to measure puck control on a course. The course was 180 feet in length with 9.18 m separating each cone, the first cone was positioned 1.22m from the start-finish line. Bosco and Gustafson (1983) reported that the reliability of the puck-carry test adopted from the Merrifield and Walford Battery of Ice Hockey Skill Tests was 0.93 and the validity was 0.96. The players started from a designated location and weaved in and out of the cones until the player reached the last cone, upon reaching the last cone the players skated in a semi-circle around the cone and headed back to the start/finish line. Basically, when a player weaves through cones, he/she alternates which side of the cone to pass by, first cone on the left side, second cone on the right side etc. Hansen et al. (1970) stated that tests of this nature could be performed in a short period of time, as well, the reliability of this test can be fairly high if the control course (distance between cones, etc.) is standardized.

The Merrifield –Walford Ice Hockey skill tests consisted of five tests that included a shooting and passing test. However, Bosco and Gustafson (1983) eliminated this test because it was of low reliability. Merrifield and Walford (1969) indicated that the reliability for a shooting test could be increased to an acceptable level if there was a large number of trials and participants (Collins and Hodges, 1969). The current author feels that despite the fact these tests were of low reliability, tests of this nature are important to the current study as the tests are game-like and evaluate skills players perform during the course of a game. Reliability may be sacrificed for validity in field tests as opposed to lab tests, but tests that are specific to game situations are important for player development and evaluation.

The second test that was taken from the study by Hansen et al. (1970) was the accuracy shooting test. The player shot from a designated distance and attempted to shoot the puck through an opening in a plywood board placed in front of the net. A similar test is performed at the N.H.L. All-Star games. The player shoots from a distance of 6 m from the goal line and attempts to hit the four targets placed in the corners of the net (Tredree, Cechowski, Inglis, Rinaldi, Young, 2000). Hansen et al. (1970) stated that this test is practical and easily applied. In addition, if the targets are the same size, placed in the same area of the goal and shooters release the puck from a pre-determined distance, the test is very reliable.

Hansen et al. (1970) evaluated one passing/receiving test, however, he stated that the instructions are unclear and it is difficult to estimate the distance between players. Two players stand a predetermined distance apart from one another and attempt to make as many passes as possible within a certain period of time. This is not a very reliable test as the performance of one player depends on the performance of his/her partner.

The N.H.L. Skills Competition (Tredree et al., 2000) also includes a rapid fire test, and a breakaway test. The rapid fire test involves three players, one shooter and two passers. The shooter stands six metres from the goal and receives four passes from each of the players located at the sides of the net. The passers alternate and the shooter attempts to hit as many of the four targets as possible in eight seconds. The targets are 38 cm in diameter and are located in the corners of the net. If the player contacts the four targets in less than eight shots, the test is completed. A shot is not scored as a hit if the same target is hit twice.

The breakaway test is just as it is named. The player begins from centre ice and must attempt to score on the goalie by means of a shot or deke; rebounds are counted only if the player is moving continuously in a forward direction.

As mentioned earlier, literature is lacking in the area of skill tests in the sport of ice hockey. Many of the tests must be modified to meet the investigator's and players' needs and to increase the reliability of the test. This is an area of literature that definitely needs to be enhanced to include standardized skill testing procedures for players and goalies, similar to the AAPHER Basketball Skills Test Manual for Girls (1966).

CHAPTER 3

METHODS

The purpose of this study was to evaluate several components of women's hockey and determine the effects of a light weight puck on the attitude and skill development of the players. Several tools were used to accomplish this including three dimensional filming and video analysis of the wrist shot, five different skill tests, and attitudinal data obtained from pre and post test surveys. During the wrist shot filming and the skill tests, players were required to use all four puck weights, the 4.5 oz puck, the 5.0 oz puck, the 5.5 oz puck and the regulation 6.0 oz puck. Wrist shot film analysis was utilized to investigate the biomechanics of the wrist shot and determine if the players' technique changed when using pucks of various weights. Skill tests included accuracy shooting, rapid fire, puckhandling, passing, and breakaway drills. The performances of the players and goaltenders were recorded with each of the four puck weights and results were analyzed to evaluate the effects of lighter pucks on skill performance. In this type of study it was important to identify the technical implications of a lighter puck on player development and how the players would feel if a lighter projectile were adopted into their sport. The participants were given the opportunity to state any comments or concerns they may have had on the use of a light weight puck in women's hockey through surveys distributed before and after on-ice testing.

Wrist Shot Analysis

Subjects

Twelve female hockey players from the Canadian National Women's Senior Team served as subjects for the film analysis. All assessments took place at the team's training site, the Father David Bauer Olympic Arena in Calgary, Alberta. Cameras were placed in front and to the side of the subjects to obtain a sagittal and frontal view of the players executing a wrist shot. This camera configuration allowed for a three dimensional analysis of the technique of the player while executing a wrist shot.

The subjects had been members of the Canadian National Team for a minimum of 1 year. The majority of the shooters, selected by the coach, were highly skilled in that the players possessed a wrist shot of high velocity and accuracy. Subjects were included on the basis that they were a healthy female, in accordance to their pre-season medical, and were 22 years of age or greater. In addition, players must not have experienced upper body injuries in the past three years that had kept them out of competition for more than four weeks. Prior to testing players were required to complete a personal consent form (Appendix A).

Pre-activity warm-up

Warm-up was used for two reasons: a) to reduce the risk of injury while performing the experimental protocol by warming up the muscles and joints involved in the activity and b) to familiarize the subjects with the four pucks of different weights, the standard (6 oz) puck and the three newly designed pucks of lighter weight (4.5 oz, 5.0 oz, and 5.5 oz). Subjects were required to perform ten wrist shots with each puck in a randomly selected order determined before testing. Subjects were assigned a random order for the puck weights to eliminate fatigue as a variable. For example, some subjects performed the test with the 4.5 oz puck, then the 6.0 oz puck, followed by the 5.5 oz puck and finished off with the 5.0 oz puck. Each player was instructed to perform their warm-up when the player preceeding them began the experimental protocol. Before the players performed the ten wrist shots, they were required to stretch as they would prior to a game or practice. However, because there was a large variability in the stretching routines between players, stretching was not standardized nor recorded.

Filming technique

Two cameras were used for video analysis, each filming at 30 Hz or 30 frames per second. The cameras were placed perpendicular to one another which allowed for a sagittal and frontal view of the shooter. In order to place the sagittal view camera (camera 1) at an angle of 90 degrees to the frontal view camera (camera 2), it was placed on top of the goal net. Cameras placed perpendicular to one another work optimally for line intersections when using the Direct Linear Transformations (DLT) method (Peak Technologies, 1994). The sagittal view of the player was filmed using a PANASONIC PV-S770A-K® model while the frontal view was recorded with the PANASONIC PV-4600-K® model. Camera 1 (Figure 3-1) was placed in a protective plexiglass box lined with foam to absorb the shock of an incoming puck.

A cement brick was placed between the bottom of the box and the goal net at the rear of the box to angle the camera towards the shooter. This allowed for a full view of the subject's body and stick. The protective box was secured to the net by four rubber bungee cords. Two of the cords were hooked together and placed behind the lip of the opening at the top of the box and attached to the front of the mesh on the top of the net. These cords prevented posterior translation of the box and eliminated the possibility of it sliding off the net towards the boards. The other two cords were hooked together and placed on the anterior and superior aspect of the box and strapped tightly against the cross bar of the goal net. The box was placed in the center of the top of the net and was located 6 metres from the placement of the puck.

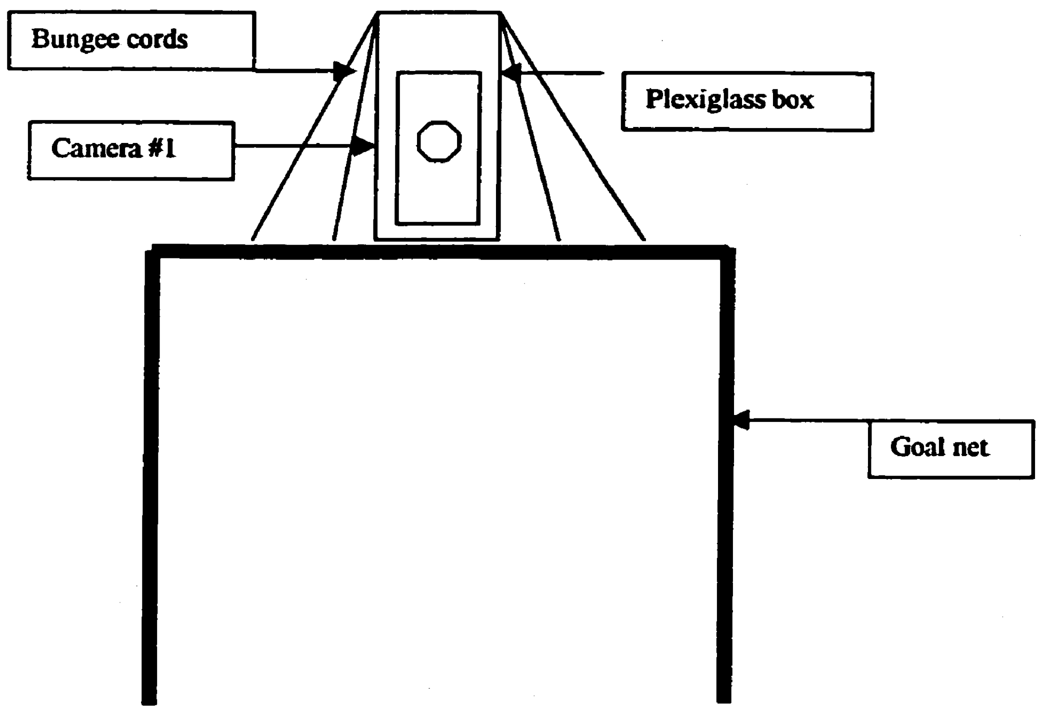


Figure 3-1 Frontal view (camera 1) camera set up on top of goal net.

Camera 2 (Figure 3-2) was secured to a tripod about four metres from the location of the puck and perpendicular to camera 1. Each camera was placed on manual focus mode and set at a shutter speed of 1/1000. This camera set-up was tested in a pilot study performed on Monday, June 12, 2000 in the Max Bell Arena at the University of Manitoba (Appendix B).

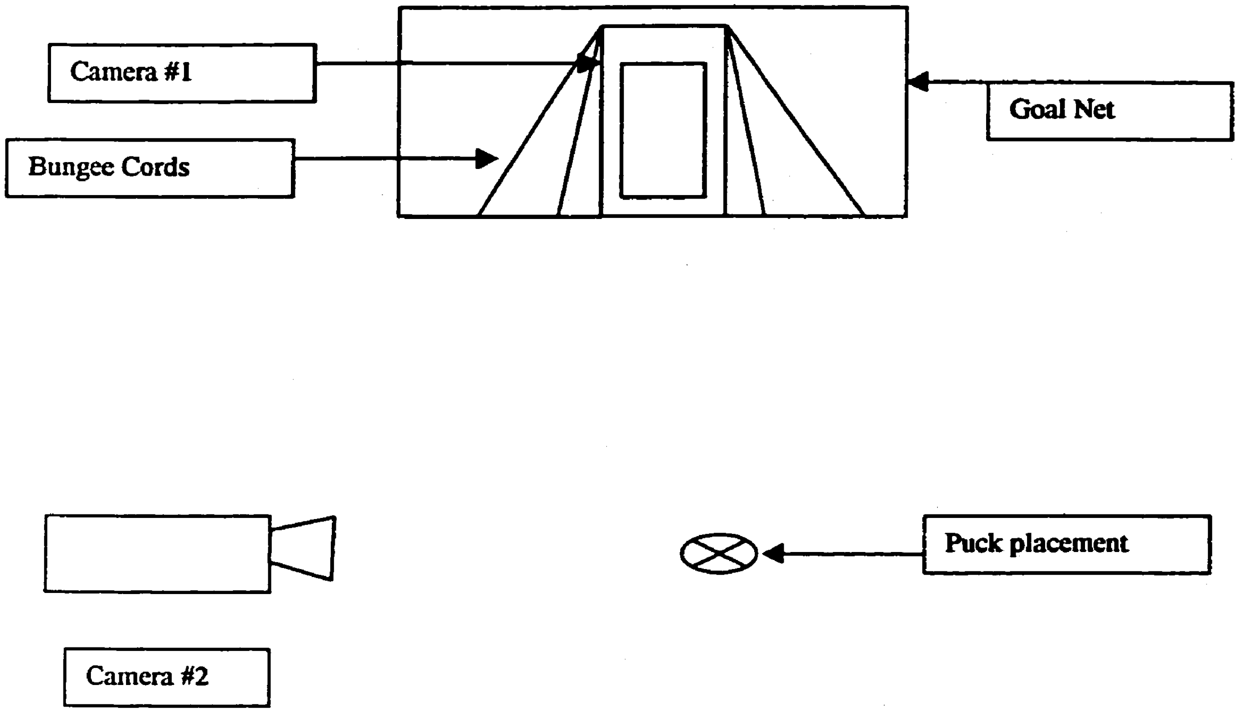


Figure 3-2 Overhead view of camera set-up.

Following camera set-up, the cameras were calibrated using a calibration tree from Peak Technologies. The calibration tree (Figure 3-3) consisted of eight rods screwed into a metal block placed on a tripod. Each rod had three reflective balls on it at a known distance from one another. In total, there were 24 balls on the tree that were used for camera calibration. The calibration tree was placed directly over the spot marked on the ice where the puck was placed to ensure that it encompassed the area that was occupied by the shooter. It is important to note that movements beyond the area of the calibration tree are susceptible to large errors. Angulo and Dapena (1992) stated that video analysis within the volume of the calibration tree are precise enough for most practical purposes.

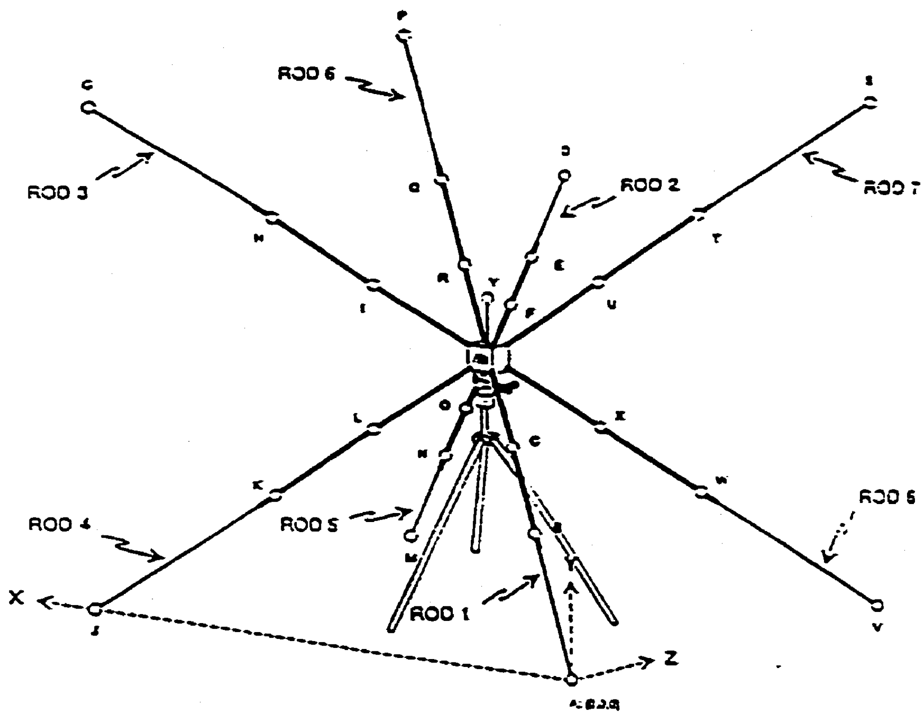


Figure 3-3 Calibration tree designed by Peak Technologies. (From Peak Performance Technologies, 1994)

Filming Protocol

The pucks were positioned 6 meters from the center of the goal net between the two face-off circles. A target 30 cm in diameter was suspended from the cross bar of the goal net and hung approximately in the vertical and horizontal center of the goal. Left handed players shot first to accommodate for the camera set-up followed by the right handed shooters after the frontal view camera (camera 2) had been placed on the opposite side of the shooting area. Before the right handed players proceeded to shoot, the calibration frame was placed in the shooting area, within the view of camera 2, to recalibrate the spatial frame of the shooting area. Participants were instructed to shoot at the target and each shot was recorded as a hit if it contacted the target or a miss if it the target and each shot was recorded as a hit if it contacted the target or a miss if it missed the target. The players were instructed to take a slight pause between shots and perform the wrist shot as they would in a game or practice situation. Subjects took five shots with each of the four pucks in the same order as performed in warm-up. For example, subject 1 may have shot the 5.0, 4.5, 5.5, and 6.0 oz pucks in that order while subject 2 may have shot the 6.0 oz puck, then the 5.0 oz puck, followed by the 4.5 oz puck and finally the 5.5 oz puck. Once the subject completed a total of 20 shots with the four puck weights, the test was complete and the player left the ice. At that time, the following player was instructed to perform the 20 shots with the four different puck weights, after they had completed the warm-up.

Video analysis

The researcher used video film analysis to measure puck velocity, linear displacement of the centre of gravity of the athlete, angular displacement and velocity of the stick blade, and angular displacement and velocity of the trunk and shoulders of the athletes. These are key variables in determining the effectiveness and skill level of the players. Players that shoot the puck with a great velocity usually demonstrate a greater; linear displacement of their center of gravity, angular displacement and velocity of the stick blade, and angular displacement and velocity of their trunk and shoulders than players that shoot the puck with less velocity.

Video film analysis was conducted with a video motion analysis system from Peak Performance Technologies (1994). This video analysis system consisted of Peak 5 software (version 5.2), a Sanyo GVR-SP55 video cassette recorder (Sanyo, Compton, California), a Sony Trinitron PVM 1341 color video monitor (Sony Corporation, Ichinomyia, Japan) an ALR IBM compatible personal computer (ALR Technologies, California), a NEC MultiSync 2A computer monitor (NEC Corporation, Tokyo, Japan), a Hewlett-Packard LaserJet series II printer and a Hewlett-Packard LaserJet series II printer and a Hewlett-Packard 7475A plotter printer (Hewlett-Packard Company, San Diego, California).

One of the five shots for each of the pucks was selected for 2-D analysis on the basis of accuracy and the velocity of the shot (shot with the greatest velocity). If the puck contacted the target it was selected for 2-D analysis, if the player missed the target on all three trials, the shots closest to the target were used. The most accurate shots were digitized using the Peak V Video analysis system and the puck velocities were calculated. The only point that was digitized was the center of the puck as the velocity of the puck was the only variable of interest for the 2-D analysis. The player's shot with the greatest velocity for each of the puck weights was selected for 3-D analysis described below.

A spatial model, or computer representation of a hockey player was created to define a 14 segment model of the human body. The spatial model (Figure 3-4) consisted of 25 points including points for the butt, heel and blade of the hockey stick as well as the center of the puck. For each frame of video film, 25 points on the body and stick were digitized to mark the landmarks of the shooter that defined the computerized spatial model. The centre of mass of the spatial model was calculated by the computer software and labeled as point 26. Digitization began approximately one frame before initial movement towards the net and was completed near the end of the player's follow-through.

1- right finger tip
2- right wrist
3- right elbow
4- right shoulder
5- sternum
6- top of head
7- left shoulder
8- left elbow
9- left wrist
10- left finger tip
11- middle of hips
12- right hip
13- right knee
14- right ankle
15- right heel
16- right toe
17- left hip
18- left knee
19- left ankle
20- left heel
21- left toe
22- stick butt
23- stick heel
24- stick toe
25- centre of puck

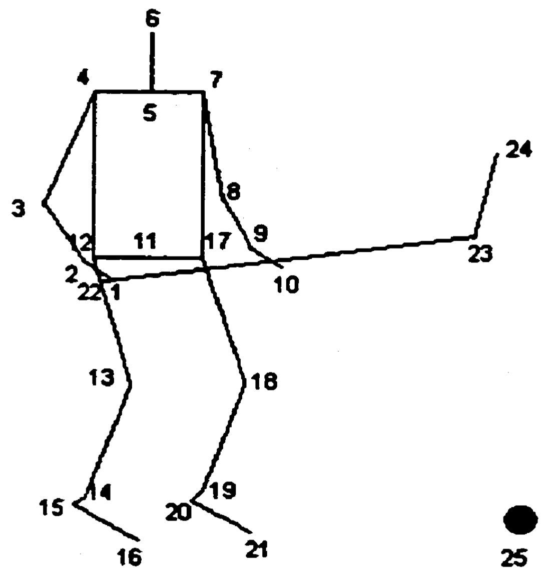
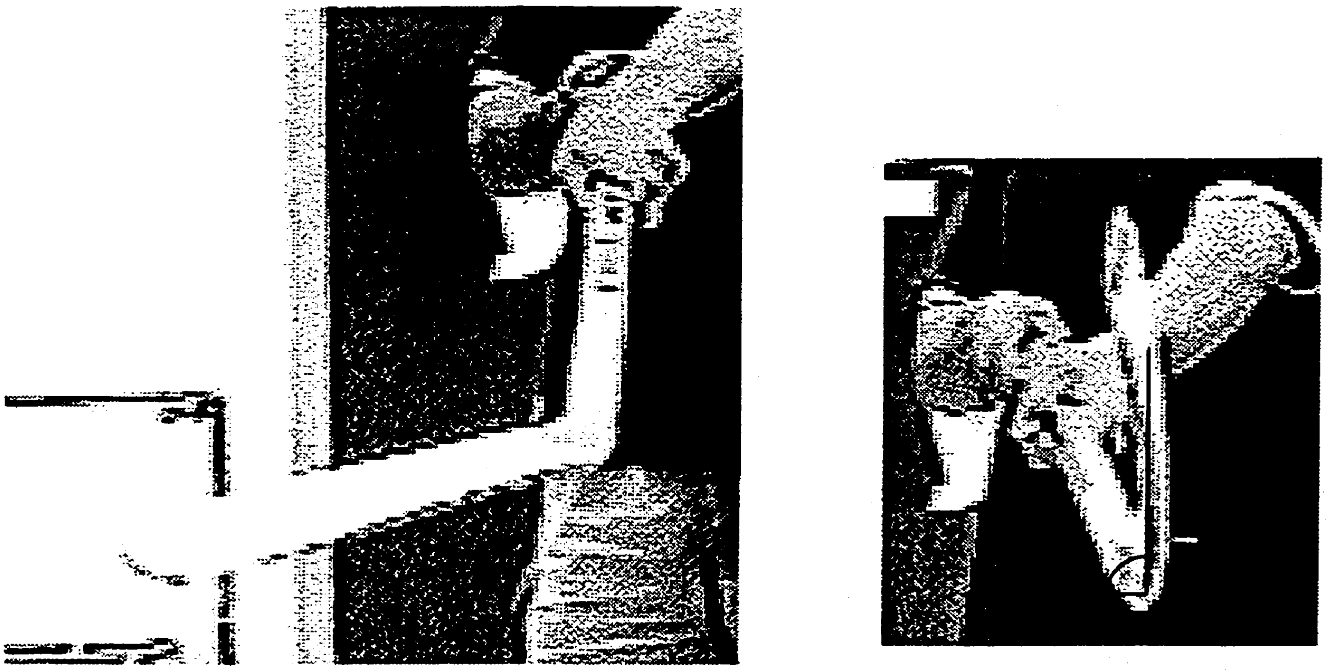


Figure 3-4 Twenty-five point spatial model of a hockey player.

The first variable calculated was the resultant velocity of the puck. Although the velocity of the puck was calculated in the 2-D analysis, variables calculated from a two camera set-up, as opposed to a single camera, are more accurate.

Angular displacements and velocities of the stick blade were calculated and used to estimate the amount of pronation for the forearm of the bottom hand on the hockey stick. As a player executes the wrist shot, the stick is grasped firmly in the hand and it can be assumed that the stick does not rotate in the player's hand during execution of the shot. Figure 3-5a demonstrates that as the blade of the stick is rotated anteriorly 90 degrees, the bottom hand on the stick has pronated 90 degrees from a neutral position. During pronation of the forearm, of the bottom hand on the stick, the elbow is placed in extension and the shoulder joint remains neutral. Therefore, any movement of the bottom hand on the stick into a pronated position is a direct result of pronation of the forearm and not flexion/extension of the elbow or medial/lateral rotation of the shoulder. Rotation of the stick blade in the transverse plane is a result of pronation of the forearms (Figure 3-5a).



(a) (b)

Figure 3-5 (a) Stick blade rotated anteriorly 90 degrees, bottom arm in 90 degrees of pronation.
(b) Angle of the stick blade.

The angle of the stick blade was calculated by connecting the toe of the blade to the heel of the stick, and using the heel of the stick as the origin of the x axis (Figure 3-5b). The minimum and maximum angles of the stick were recorded from the Peak Video Analysis system, the minimum value was then subtracted from the maximum value to calculate the maximum angular displacement during the wrist shot. If the bottom hand on the stick pronated, the angle of the blade of the stick to the x axis was reduced and the angular velocity was derived by dividing the angular displacement (Ø) over the change in time (t). Since the velocity and displacement of the stick blade were directly proportional to the angular displacement and velocity of the pronation of the forearm, it was assumed that the forearm of the bottom hand on the stick must pronate 90 degrees to displace the blade of the stick by 90 degrees.

In addition, rotation of the hips, and shoulders were calculated using the Peak V Video Analysis system. The magnitude and sequence of rotation of the hips and shoulders determines the effectiveness of the wrist shot. Peak angular velocity of the hips should occur just prior to peak angular velocity of shoulder rotation.

In order to calculate hip angles, a line was drawn from the center of one hip joint to the center of the other hip joint (Figure 3-6a) and connected to the z axis which originated from the center of the right hip, for a right handed shooter (Figure 3-6b). If the shooter was left handed the origin of the z axis was located at the center of the left hip joint. As a player's hips rotated towards the goal, the angle between the z axis and the hips increased and became an obtuse angle. The greater the angle formed, the greater the angular displacement of the hips. Angular velocity was calculated by dividing the angular displacement of the hips over the time for which that displacement occurred. The less time it took for the players to rotate their hips, the greater the angular velocity of hip rotation.

Figure 3-6 (a) Line connecting the center of one hip to the center of the other hip.
(b) Line representing the z axis from the hip most distal to the goal net.

The angle of the shoulders was calculated by connecting a straight line from the joint center of one shoulder to the joint center of the other shoulder (Figure 3-7a) and connecting this line to the z axis which originated from the shoulder most distal from the goal net (Figure 3-7b). For left handed shooters the origin of the z axis was placed at the center of the left shoulder joint whereas the origin for right handed shooters was placed at the center of the right shoulder joint. Therefore, as the shoulders of the player rotated towards the goal net, the angle between the z axis and the shoulders (angular displacement of the shoulders) increased. The quicker the rotation of the shoulders, the greater the angular velocity of the shoulders.

Figure 3-7 (a) Line connecting the center of each of the shoulder joints.
(b) Line representing the z axis from the shoulder most distal to the goal net.

The displacement of the center of gravity of the player in the x and y planes were recorded to analyze the weight shift of the athlete during the wrist shot. Displacement of the center of gravity of the athlete along the x axis indicates a horizontal shift of weight from one leg to the other, whereas displacement of the center of gravity along the y axis represents a weight shift in the vertical direction. If the line of gravity (an imaginary line running perpendicular from the center of gravity to the ground) lies in the center of the base of support of the athlete, the weight of the athlete will be evenly distributed on each leg (Figure 3-8).

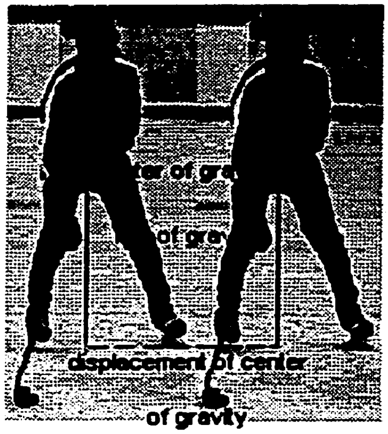


Figure 3-8 Representation of the center of gravity, the line of gravity and the linear displacement of the center of gravity of the player.

As the center of mass or gravity shifts toward one leg of the athlete, more weight is placed on that leg. The greater the horizontal displacement (along the x axis) of the center of gravity, the greater the weight shift. Highly skilled hockey players demonstrate a large horizontal weight shift towards the goal net during the wrist shot and minimal displacement of the center of gravity in the vertical direction (along the y axis).

Statistical analysis

A repeated measure analysis of variance was used to assess the effects of puck weight on the wrist shot performance in the female hockey player. Data from the wrist shots for the 4.5, 5.0, 5.5, and 6.0 oz puck were compared for each individual as well as the collective results of each participant for the four different puck weights. The number of participants (n=12) was not great enough to allow for group comparison of the data as the power of the test would be too low. Subjects were randomly assigned the order in which the pucks were used during the skill tests to eliminate fatigue as a variable.

Hockey Skill Tests

The hockey skill tests were designed to evaluate a number of different skills that female hockey players and goalies execute during the course of a hockey game. In total there were five different skill tests that assessed puckhandling, passing, shooting and goaltending. Skill tests were placed on different sections of the ice and labeled stations one through five as the Accuracy Shoot, Puckhandling, Rapid Fire, Breakaway, and Passing/Receiving skill tests, respectively.

Subjects

Subjects for the hockey skill tests consisted of 25 members of the Canadian National Under 22 Women's team. Approximately half of the players had competed for the Under 22 National team in the past while the other half were members of the National team for the first time. The skill tests were performed at the Father David Bauer Olympic Arena in Calgary, Alberta. The assistants for the testing at the team's training center included employees of the Canadian Hockey Association. A total of ten assistants were used to ensure two volunteers were at each testing station during the skill tests. Players were split up into two ice sessions of one hour, the first ice session involved 12 players and two goalies while the second hour had 11 players and the same two goalies. Prior to testing, the players received a brief description of the tests and warm-up, where the stations were located on the ice and which station they were to begin at. There were five stations on the ice and each player spent approximately 10-12 minutes at each station. The players were broken up into groups of two or three and randomly assigned to their beginning station. Players were required to fill out a personal consent form prior to testing that briefly explained the battery of tests, assured the subjects they had the right to withdraw and guaranteed data from the study were kept confidential. Players were included on the basis that they were a healthy female in accordance with their pre-season medical and had not experienced an injury to any part of their body in the past three years that had kept them out of competition for more than four weeks. It should be noted that one of the goalies sustained an injury during the Breakaway portion of the skill tests in the first ice session and was unable to continue. Therefore, only 12 subjects performed the Rapid Fire test and 12 subjects competed in the Breakaway skill test.

Pre-activity warm-up

Warm-up was used for two reasons; a) to reduce the risk of injury while performing the experimental protocol by warming up the muscles and joints involved in the activity and b) to familiarize the subjects with the four pucks of different weights, the standard (6oz) puck and the three newly designed pucks of lighter weight (4.5 oz, 5.0 oz and 5.5 oz). The warm-up was 10 minutes in duration and subjects had 2 1/2 minutes with each puck. The participants were able to shoot, pass, or stickhandle the puck, the main objective was to let the subjects get accustomed to the lighter pucks. The order that the players used the pucks was determined prior to testing and each player warmed up with the four pucks in the same order as they would perform the test. For example, it may have been determined prior to testing that subject 1 would perform the skill tests in the following manner; the 4.5 oz puck would be used first followed by the 6.0 oz and 5.5oz puck and finally the 5.0 oz puck. The player would use the same order of weighted pucks for every exercise in the battery of skill tests. Warm-up was performed just prior to commencement of the skill tests.

Testing protocol

The battery involved five skill tests. Each player was randomly assigned to one of the skill test groups to begin the testing session. Each skill test group consisted of two or three players. After completion of each test the subjects were required to wait for the other members of the group to finish. Players were instructed to wait in their group to avoid distracting any of the other players as an audience can have a strong negative affect on developing players. When each of the players had completed their respective tests the whistle blew and the groups rotated to the next station. All subjects rotated from station to station in numerical order after each group had completed their respective tests. This ensured the players had a sufficient rest period to eliminate or minimize fatigue as a variable. In addition, the random selection into groups at the beginning of testing minimized the effects of fatigue on performance of the latter drills in the testing protocol.

The Accuracy Shoot (Figure 3-9) was labeled station or test 1. A circle was spray painted on the ice six metres from the center of the goal. Four Plexiglass targets, 30 cm in diameter were placed in the corners of the net, suspended by nylon straps to the cross bar and secured to a nylon strap that ran from one post to the other near the bottom of the net.

The straps prevented excessive movement of the targets when the targets were contacted by a puck, allowing the players to continue the test without delay. Players were given six pucks and the goal was to contact each of the four targets in as few shots as possible.

If the four targets were hit before all six shots were taken, the player was not required to shoot the final two pucks.

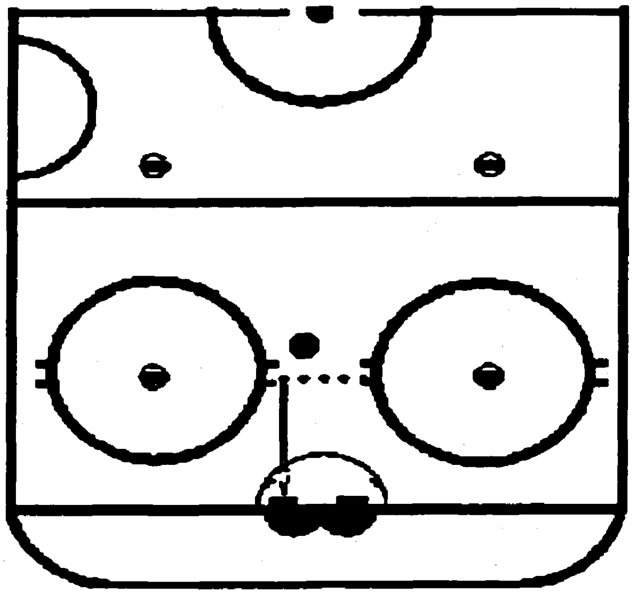


Figure 3-9 Diagram of the Accuracy Shoot skill test (Test #1).

Subsequently, if the player did not contact all four targets with the six pucks, the test was stopped and the score of the player was recorded. Scores were recorded as the number of targets hit / the number of shots taken. The players completed the test using the same order of pucks as in warm-up, each subject shot all four puck weights for a total of 24 shots before the next player began the test.

Skill test 2 was the Puckhandling test (Figure 3-10) in which six cones were placed in a straight line 6 metres apart. Players began the test in the start/finish gate located 6 metres from the first cone. Forward movement of the player started the stop watch and the player proceeded through the cones. The player was required to stick handle through the cones alternating the sides of each cone the player skated beside. When the player arrived at the last cone, she was required to round the cone and continue through the course, around the cones to the start/finish gate.

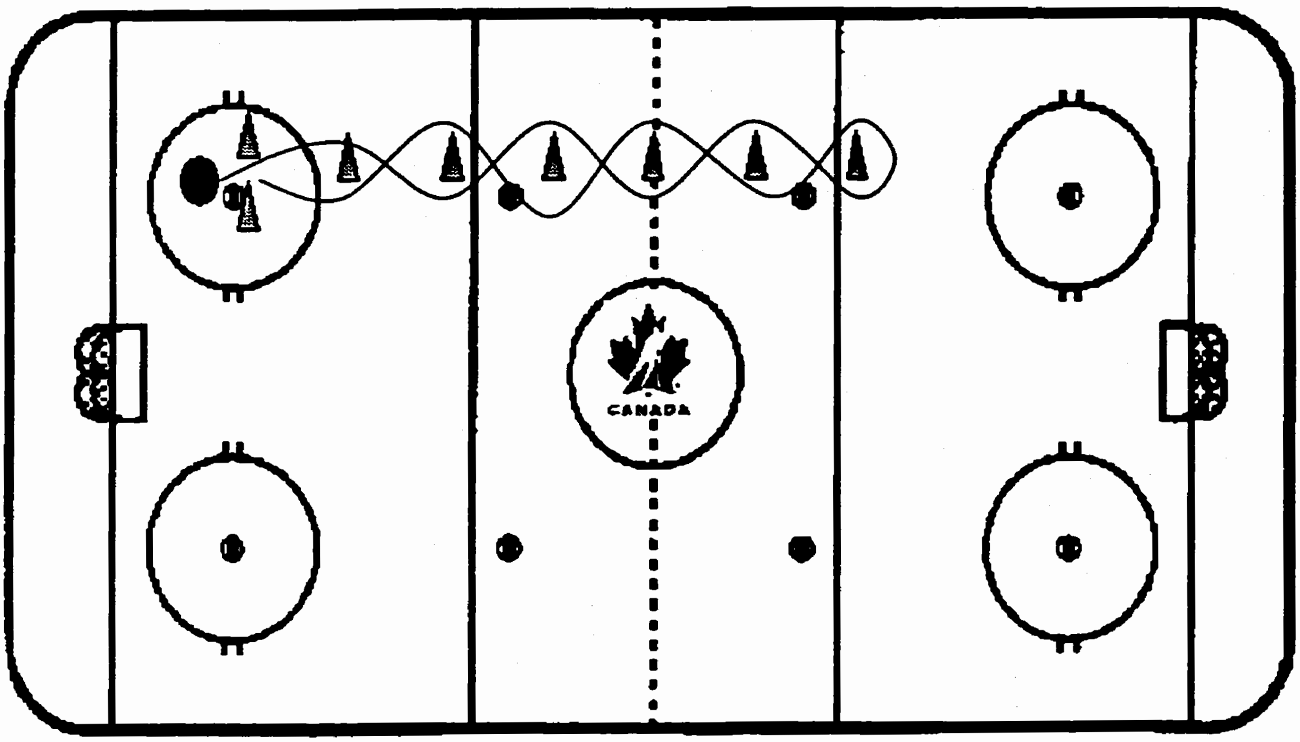


Figure 3-10 Diagram of the Puckhandling test (Test #2)

The clock was stopped when the first body part, not the stick, of the individual entered the gate. If the player lost the puck during the course of the test, she was required to retrieve the puck and enter the course where the puck was lost. The time continued to run until the player completed the course. The player performed the test with one puck and rested until the other members of the group had completed their first trial. Participants then performed the test with their next puck weight. The Puckhandling test was more physically demanding than the other tests and an adequate rest interval was required to minimize the effects of fatigue on test performance. When all the players at this station had completed the test and the whistle blew the group moved on to the Rapid

Fire skill test. Unfortunately, due to time restraints, each player was only able to complete one trial with each of the four puck weights.

The Rapid Fire skill test (Figure 3-11) was the third of the five hockey skill tests. Five pucks were placed at designated locations (indicated by spray paint on the ice) 6-7 metres from the goal line. Players were required to shoot all the pucks within ten seconds or the test had to be repeated. The goalie was required to have her skates in the goal crease at all times during the test. If the goaltender left the crease, the test was stopped and performed again. The time required by the players to shoot all five pucks was not recorded but if it exceeded ten seconds the trial was repeated. Shots were scored as either a goal (g), a save (s), or a miss (m). A shot that missed the net or contacted the goal post was considered a miss and not a save by the goaltender.

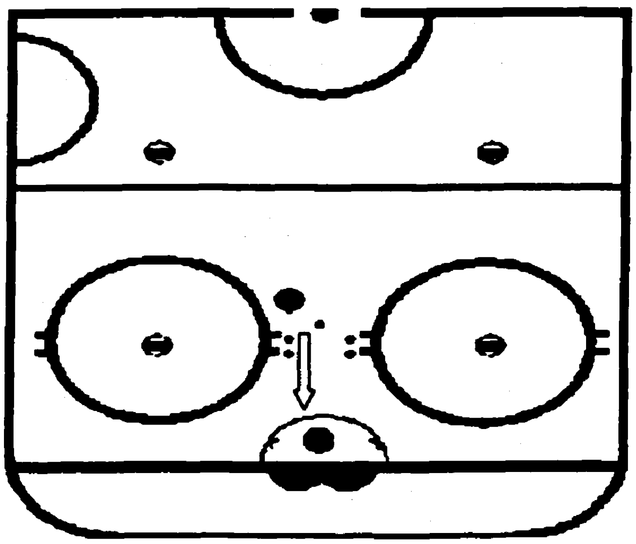


Figure 3-11 Diagram of the Rapid Fire skill test (Test #3).

After player 1 completed the five shots with each of the four pucks for a total of 20 shots in the same order as warm-up, the next player began. It should be noted that the order of players was the same for each test to ensure subjects received close to the same rest period.

The Breakaway skill test was designated the fourth test in the battery of skills tests (Figure 3-12). Although breakaways include puckhandling and shooting, the researcher felt this test was necessary as it is very similar to a game situation for the players and the goaltenders.

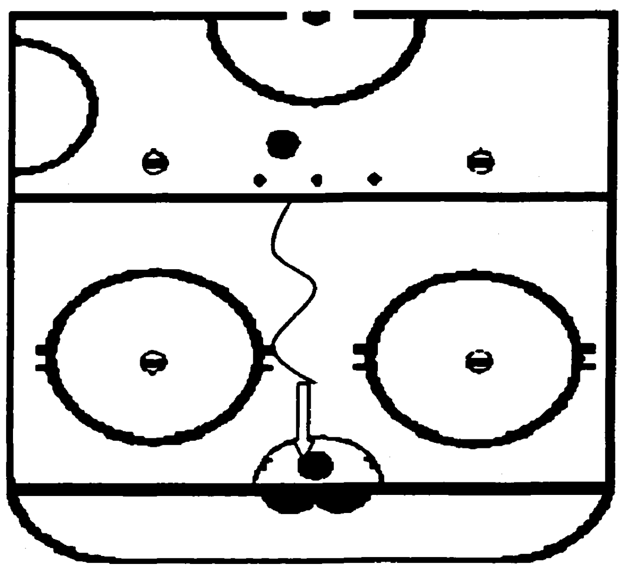


Figure 3-12 Diagram of the Breakaway skill test (Test #4).

Four pucks were placed on the blue line and the player made four consecutive attempts to score on the goalie. Two sets of puck weights were placed on the blue line for the trial. Each player completed two trials, therefore two breakaways were performed with each puck weight. Puck weights were selected in the same order as the other four skill tests. The goalie was instructed to stand on the goal line until the player contacted the first puck and returned to the goal line after each shot was taken until the next puck was touched. Players were not allowed to score on rebounds and had to move continuously in the forward direction until the shot was taken. The attempt was recorded as either a goal or a save. Contrary to the Accuracy Shoot, if a player missed the net, it was considered a save by the goalie as a goalie often forces the player to shoot at a poor angle. Each player performed one trial with the puck of designated weight and then rested until the other players had completed their first trial.

Passing and Receiving was the fifth test performed (Figure 3-13). The player was positioned six metres from the instructor and was required to remain within the 2metre diameter passing circle. Again, this circle was marked on the ice with paint and if the player left the circle during the test, the test was stopped and the stop watch was reset.

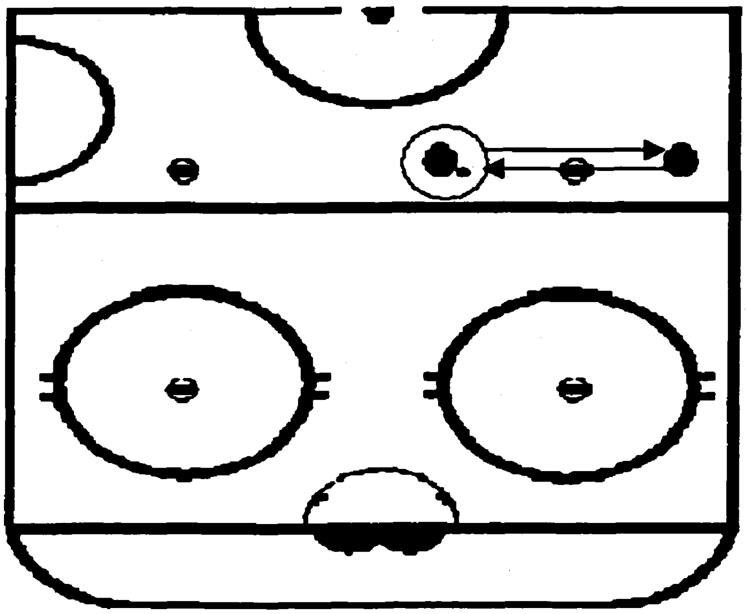


Figure 3-13 Diagram of the Passing/Receiving skill test (Test #5)

The player was required to give and receive five passes as quickly as possible. The stop watch began when the player released the first pass and stopped when the player received the fifth pass. If the puck was mishandled or a poor pass was made by the instructor (missed the player's stick) the test was stopped, the clock was reset, and the player restarted the test. If the puck was mishandled by the player, or the player missed the instructor's stick, the puck was retrieved and the time continued to run until the player completed the test. The time required to complete the five passes was recorded at the end of the trial. Contrary to previous tests each subject performed two trials with each puck before the next person performed the skill.

The complete on-ice set-up of the five skill tests is outlined in Figure 3-14.

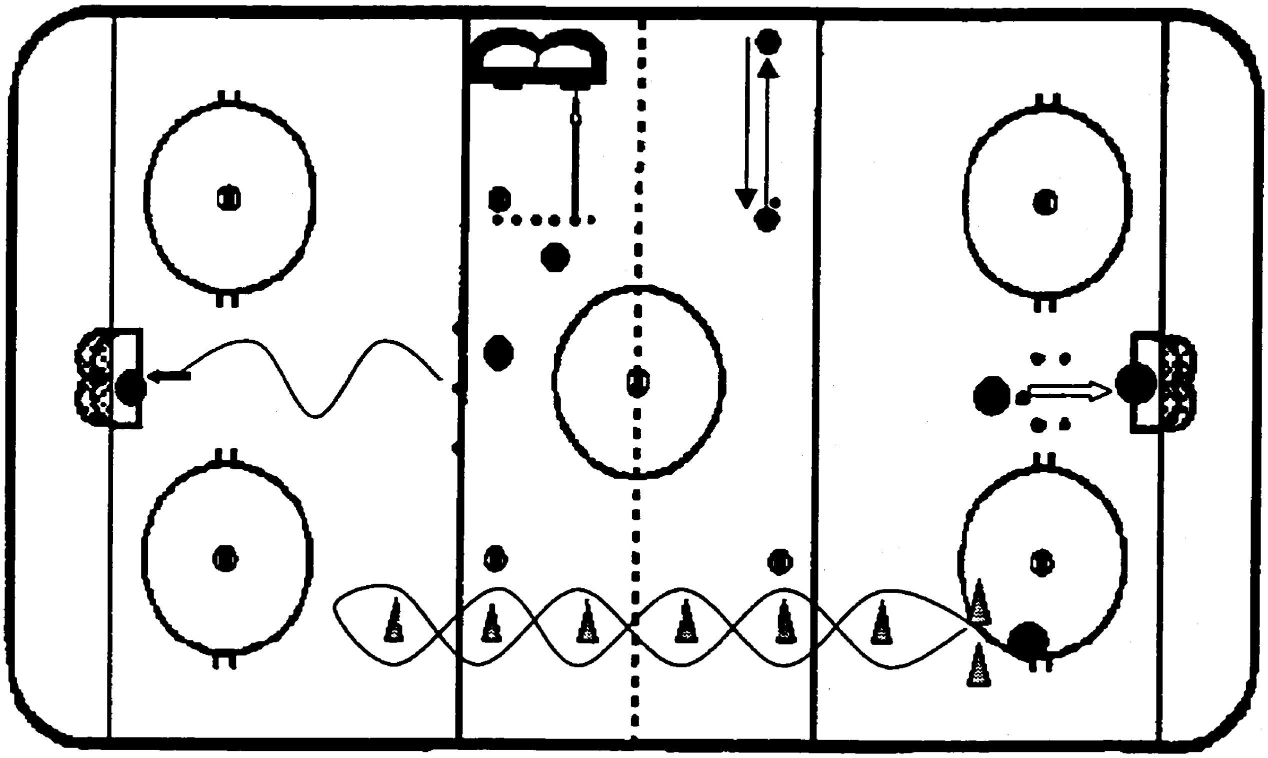


Figure 3-14 Diagram of the on-ice set-up of the five skill tests.

Statistical analysis

A repeated measure analysis of variance (ANOVA) was used to analyze the results of the five skill tests. Refer to individual data in Appendix h. The results of each of the skill tests were compared between the four puck weights.

Surveys

The participants were required to complete a survey at the beginning and the end of wrist shot filming and skill test ice sessions. The surveys were designed to assess the attitudes of the players towards the use of a light weight puck in women's hockey before and after the subjects had experimented with the new projectiles. The pre-test survey (Appendix D) attempted to obtain information on ages, skill level, and experience of the player as well as their attitudes toward the idea of using a lighter puck in women's hockey.

The post-test survey (Appendix E) questioned subjects on whether they thought the light weight puck actually did make a difference, and if their attitudes toward the use of a light weight puck had changed after experiencing the new puck. One question in the survey required the players to comment on which of the three lighter puck weights they would prefer if a lighter puck were adopted into the sport.

The main goal of the surveys was to get a general overview of the thoughts of female players towards the use of a light weight puck. Attitudes of the female players before and after testing will be considered when the decision is made to reject or accept the new puck.

CHAPTER 4

RESULTS

Wrist shot analysis

A repeated measure analysis of variance of the results obtained from the 3-D analysis yielded no significant differences in the mean resultant puck velocities (PV) between the four puck weights (Table 4-1). The results did demonstrate that wrist shots with the lighter pucks could be shot with a greater resultant puck velocity than the regulation, 6.0 oz puck but the results were not significant (Figure 4-1). A negative correlation was evident, but not significant, between puck weight and puck velocity. Table 4-1 shows that the greatest mean resultant puck velocities were achieved with the 4.5 oz puck (20.432 m/s) and the slowest (19.533 m/s) with the 6.0 oz puck. Individual results for the wrist shot variables are included in Appendix G.

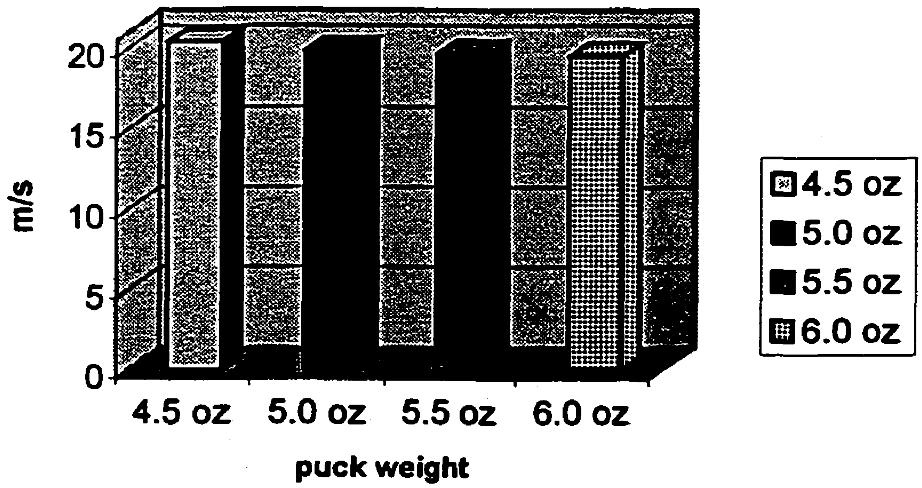


Figure 4-1. Mean resultant puck velocity (PV) attained during the wrist shot using pucks of four different weights (n = 12).

Table 4-1
Comparison of kinematic variables between pucks of four different weights

	4.5 oz		5.0 oz		5.5 oz		6.0 oz			
	M	SD	M	SD	M	SD	M	SD	f value	p value
PV (m/s)	20.432	1.264	19.880	1.734	19.683	2.087	19.533	1.755	0.62	0.61
SBD (deg)	75.866	20.180	85.405	14.675	76.042	24.597	78.711	22.347	0.52	0.67
SBV (deg/s)	1373.911	722.419	1626.177	849.093	1200.092	774.258	1471.963	898.848	0.58	0.63
HD (deg)	2.394	18.928	9.901	18.470	9.443	20.597	11.940	18.193	0.57	0.64
HV (deg/s)	152.067	149.998	251.035	88.556	144.868	157.912	135.823	154.149	1.76	0.16
SD (deg)	53.815	8.145	51.321	6.480	52.963	9.268	52.520	9.507	0.18	0.91
SV (deg/s)	393.673	77.336	376.067	77.977	419.482	103.057	408.890	102.149	0.52	0.67
LDCG (m)	0.216	0.276	0.200	0.099	0.204	0.133	0.130	0.206	0.50	0.68

PV = puck velocity (m/s)	HV = hip velocity (deg/s)
SBD = stick blade displacement (deg)	SD = shoulder displacement (deg)
SBV = stick blade velocity (deg/s)	SV = shoulder velocity (deg/s)
HD = hip displacment (deg)	LDCG = linear displacment of the center of gravity (m)

The angular displacement of the stick blade (SBD) for each of the puck weights did not produce any significant results or suggest any specific patterns (Table 4-1). The players produced the greatest stick blade angular displacement with the 5.0 oz puck (85.405 deg) and the least with the 5.5 oz puck at 76.042 degrees.

Data obtained from video film, for the angular velocity of the stick blade (SBV) did not produce significant differences between the four puck weights. Table 4-1 reports that subjects had the greatest angular stick blade velocity with the 5.0 oz puck and the least with the 5.5 oz puck.

Minimum hip angular displacement (HD) was produced when the wrist shot was executed with the 4.5 oz puck and participants achieved the greatest hip angular displacement when using the 6.0 oz puck (Table 1). Data in Table 1 suggested there is a large, but similar variation between the subjects for each of the puck weights (SD 18.470 to 20.579 deg).

Results of the angular velocity of the hip did not yield significant differences between trials with each of the four puck weights. Table 4-1 shows that the maximum angular velocity of the hip was produced when the subjects shot the 5.0 oz puck.

Angular displacement of the shoulder girdle in the transverse plane (SD) did not produce any significant differences between wrist shots with each of the four puck weights (Table 4-1). Figure 4-2 suggests that mean values of angular displacement of the shoulder girdle are similar between each of the four puck weights and that the players rotated their shoulder, 51.32 to 53.82 degrees, towards the goal while executing the wrist shot.

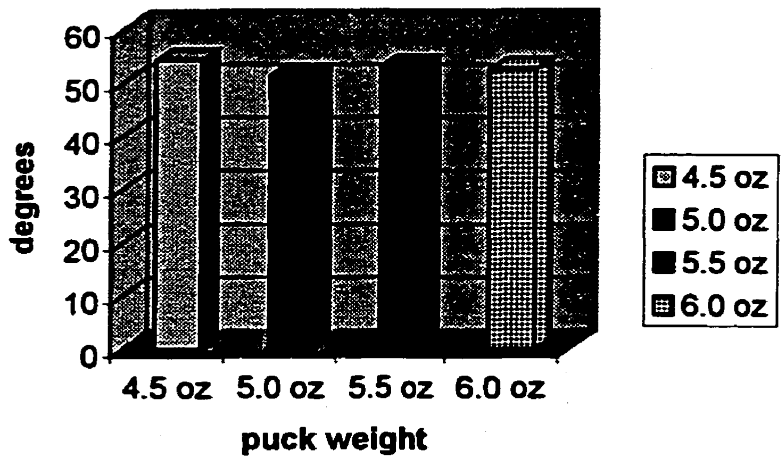


Figure 4-2. Mean angular displacement of the shoulder girdle about the tranverse plane (SD) with each of the four puck weights.

There were no significant differences in mean angular velocity of the shoulder girdle in the transverse plane (SV) around the longitudinal axis when the wrist shot was executed with each of the four puck weights (Table 4-1). Figure 4-3 shows that maximum angular velocity of the shoulder was achieved with the 5.5 oz puck at 419.48 deg/s^2 while the minimum angular velocity was 376.07 deg/s^2 with the 5.5 oz puck.

Resultant linear displacement of the center of gravity of the player (LDCD) for each of the puck weights did not yield significant differences between puck weights. Table 4-1 suggests that linear displacement of the center of gravity of the player was greatest when players executed a wrist shot with the 4.5 oz puck (0.216 m) and the least when using the 6.0 oz puck (0.13 m).

Data in Table 4-2 represents the time elapsed, in seconds, between the instant of puck release and the maximum velocity of the wrist shot variables. Results were calculated by subtracting the instant of puck release from the following variables: peak angular velocity of the stick blade (SBVT), peak angular velocity of hip rotation (HVT) and peak angular velocity of the shoulder girdle (SVT). Individual values are included in Appendix G.

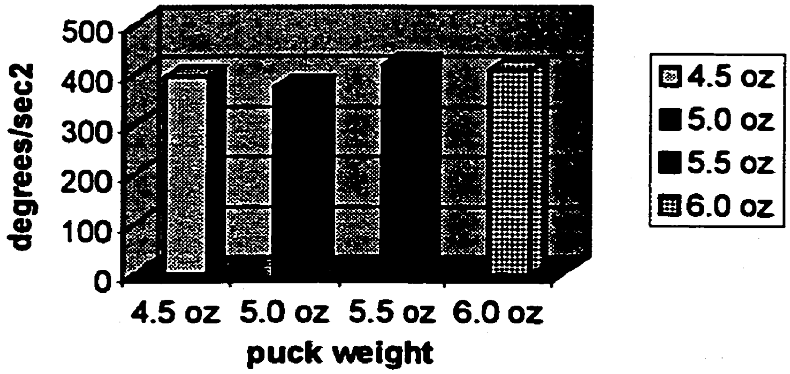


Figure 4-3. Mean angular velocities of the shoulder girdle about the transverse plane (SV) with each of the four puck weights.

Results of the time elapsed between mean angular velocity of the stick blade and puck release (SBVT) did not reveal any significant differences between puck weights. Maximum angular velocity of the stick blade occurred prior to puck release for the 4.5 and 5.0 oz pucks but not for the 5.5 and 6.0 oz pucks (Table 4-2).

The time between maximum angular velocity of the hip and puck release (HVT) was not significantly different for the four puck weights. Maximum angular velocity of the hip occurred before puck release when the players executed the wrist shot with each of the puck weights.

All subjects demonstrated maximum angular velocity of the shoulder girdle (SVT) prior to puck release. Maximum angular velocity of the shoulder girdle occurred

Table 4-2
Time between release of puck and other shooting variables for different puck weights

	4.5 oz		5.0oz		5.5 oz		6.0 oz			
	M	SD	M	SD	M	SD	M	SD	f value	p value
SBVT	-0.01	0.03	-0.01	0.01	0.01	0.02	0.00	0.02	0.58	0.63
HVT	-0.02	0.05	-0.04	0.08	-0.05	0.07	-0.02	0.06	0.63	0.60
SVT	-0.04	0.04	-0.05	0.04	-0.04	0.03	-0.06	0.03	0.84	0.48

Note. Values are were calculated by subtracting the time of puck release from the time of the maximum velocity of the wrist shot variable. Negative numbers indicate the peak velocity of the wrist shot variable occurred prior to puck release.

SBVT = time between maximum angular velocity of the stick blade and puck release (s)
HVT = time between maximum angular velocity of the hip and puck release (s)
SVT = time between maximum angular velocity of the shoulder girdle and puck release (s)

0.04 to 0.06 seconds before puck release (Table 4-2). The results were not significantly different for the four pucks of different weight.

Hockey Skill Tests

The results of each of the five skill tests are included in Table 4-3. Shooting and save percentages were recorded for the Breakaway skill test and the Rapid Fire skill test.

Results of the Accuracy Shoot skill test (AS) did not yield statistically significant results between each of the four puck weights (Table 4-3). The results suggested that the players were most accurate with the 5.5 oz puck (36%), similar to the shooting percentages (33%) with the other three pucks (Figure 4-4). Individual results for each of the five hockey skill tests are included in Appendix H.

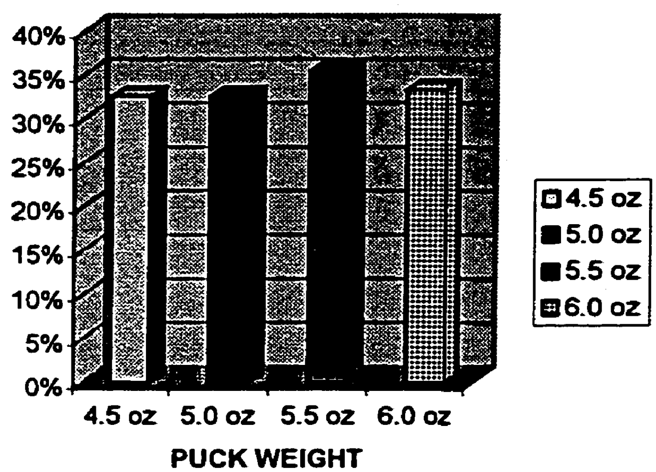


Figure 4-4 Shooting Percentages for the Accuracy Shoot skill test with the four puck weights.

The second skill test, the Puckhandling drill (PH), produced no significant difference in the time to complete the course between the four puck weights. The players had the fastest average time of 13.43 s for the 5.5 oz puck and the slowest time of 13.57s for the 5.0 oz puck .

Table 4-3

Results of the five hockey skill tests for the four pucks of different weights.

	4.5 oz		5.0oz		5.5 oz		6.0 oz			
	M	SD	M	SD	M	SD	M	SD	f value	p value
AS (%)	33	17	33	18	36	23	33	28	0.09	0.96
PH (sec)	13.5	0.47	13.57	0.71	13.43	0.46	13.54	0.59	0.25	0.86
RFS (%)	23	24	20	24	23	25	13	20	0.48	0.69
RFSA (%)	52	31	50	23	57	27	67	22	1.00	0.40
BS(%)	19	25	17	25	19	25	11	22	0.29	0.83
BSA (%)	81	25	83	25	81	25	89	22	0.29	0.83
PA (sec)	8.4	1.57	7.29	0.65	7.5	1.16	7.22	0.68	5.80*	0.001*

Note. Percentage scores were rounded to the nearest percent

*$p < .01$. (n=12)

AS = accuracy shoot (%)	BS = breakaway shooting percentage (%)
PH = puckhandling (s)	BSA = breakaway save percentage (%)
RF = rapid fire shooting percentage (%)	PA = passing (s)
RFS = rapid fire save percentage (%)	

In the Rapid Fire skill test the shooting percentage (RFS) between puck weights varied by up to 10%. The highest mean shooting percentages were attained with the 4.5 oz and 5.5 oz pucks at 23%, the lowest shooting percentage was with the 6.0 oz puck at 13% (Table 4-3). Although the results were not significantly different between puck weights, the data does suggest players shot less accurately with the 6.0 oz puck (Figure 4-5)

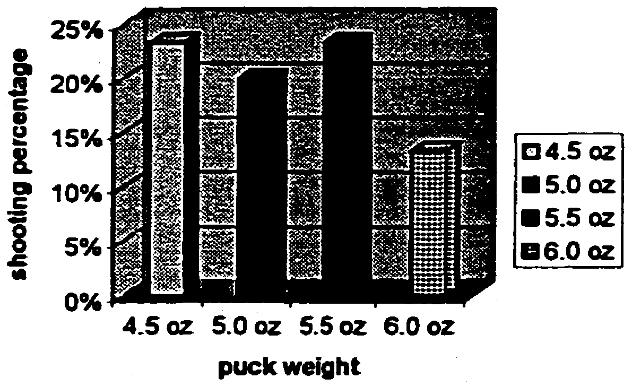


Figure 4-5 Mean shooting percentages for the four puck weights in the Accuracy Shoot skill test.

Although not statistically significant, the save percentages (RFSA) for the goalies during the Rapid Fire skill test were highest when the players were shooting the 6.0 oz puck, 10% greater than the 5.5 oz puck and 15 –17% greater than the 4.5 and 5.0 oz pucks (Figure 4-6).

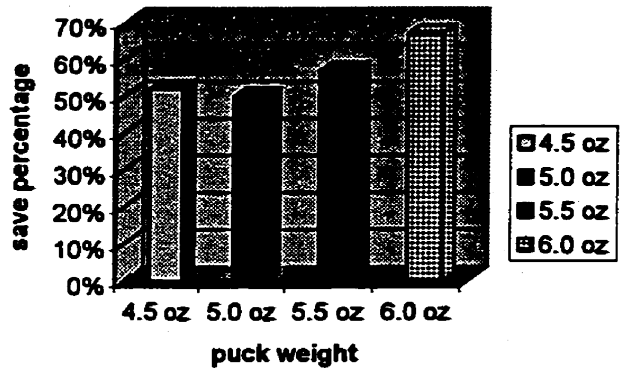
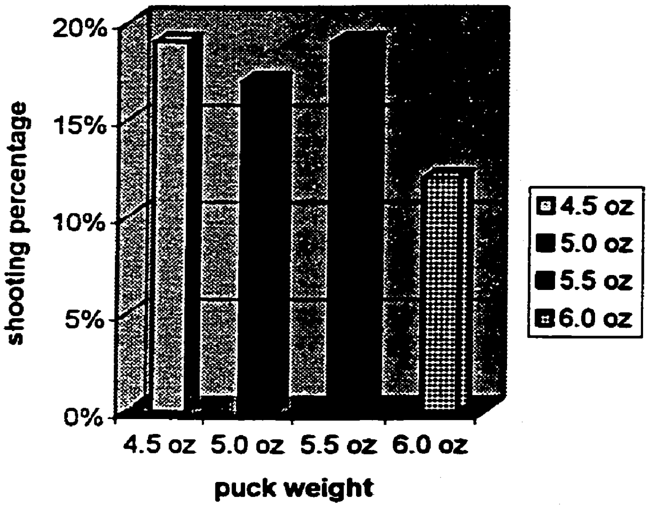


Figure 4-6 Goalie save percentages for the four puck weights in the Rapid Fire skill test.

There was no statistically significant difference between the pucks of different weights for the shooting and save percentages of the Breakaway skill test but there were some trends in the data. Shooting percentages (BS) for the fourth skill test, the Breakaway test, were highest with the 4.5 oz and 5.5 oz pucks (19%) and lowest with the regulation 6.0 oz puck at 12 % (Figure 4-7a). The save percentages for the goalies were the highest when the players shot the regulation, 6.0 oz puck (89%). The results suggested that the goalies saved more shots when the regulation puck was used as the players could not score as often as with the lighter pucks (Figure 4-7b).

The results of the Passing skill test (PA) yielded a significant difference when the players performed the skill test with the 4.5 oz puck as compared to the other three puck weights (Table 4-3), $F(3, 88)$, $p<0.01$. Results of the Tukey post-hoc test demonstrated that the mean time result for the 4.5 oz puck was 8.40 seconds, significantly slower than the time it took the players to complete the Passing skill test with the 5.0, 5.5 and 6.0 oz pucks (Figure 4-8).



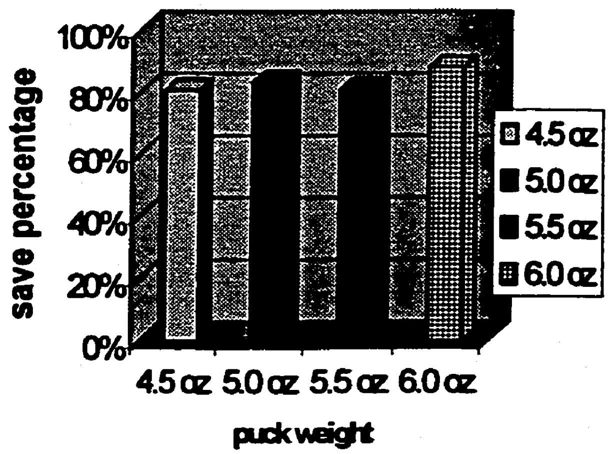


Figure 4-7(a) Shooting percentage for the four puck weights in the breakaway skill test.

b) Save percentages for the four puck weights in the breakaway skill test.

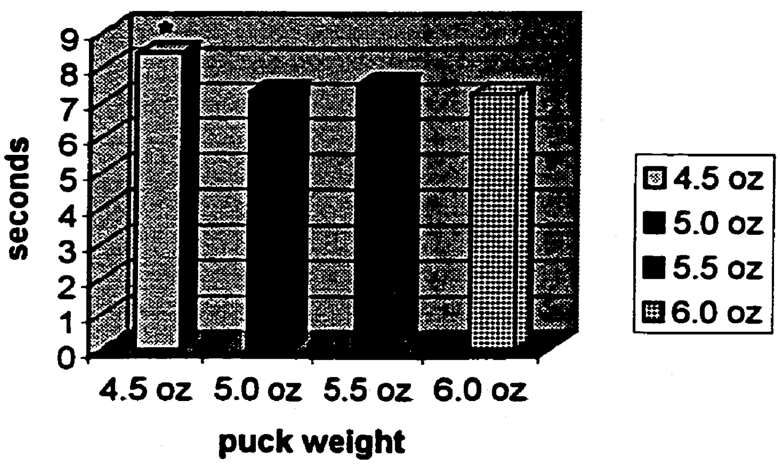


Figure 4-8 Mean times to complete the Passing skill test with the four pucks.
* Significantly different from the other three puck weights ($p < 0.01$)

Surveys

Pre-test surveys

The post-test surveys were completed by the players from both teams immediately before their respective ice sessions. The individual results of the survey are included in Appendix I. The first question related to the number of years the participants had competed in female hockey. Figure 4-9 illustrates that the majority of the NWT had played more seasons of competitive hockey than the U22 team. Ninety-two percent of the NWT had played female hockey for at least nine years whereas no members of the U22 had played for that long.

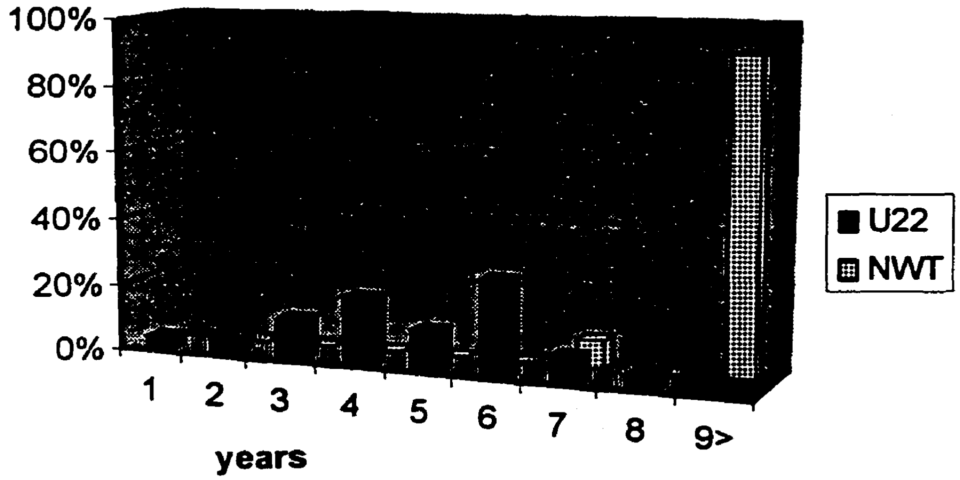


Figure 4-9 Number of years the players on the NWT and U22 team had competed in women's hockey.

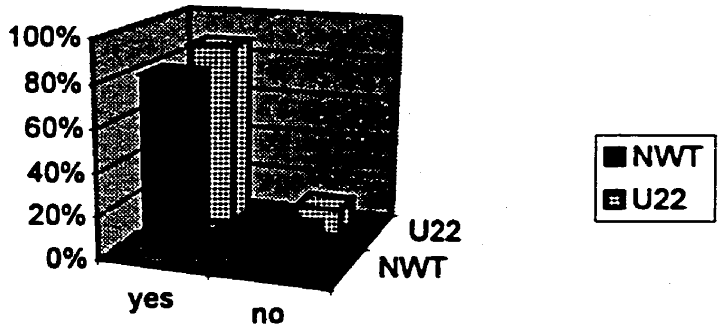


Figure 4-10 Percentage of NWT and U22 players that had previously played hockey on a men's team.

The third question of the pre-test survey asked the players to state the highest age level of women's hockey that they had participated in. Results of the pre-test survey suggest that the majority of players on each team had played women's hockey at the Senior age level (Figure 4-11).

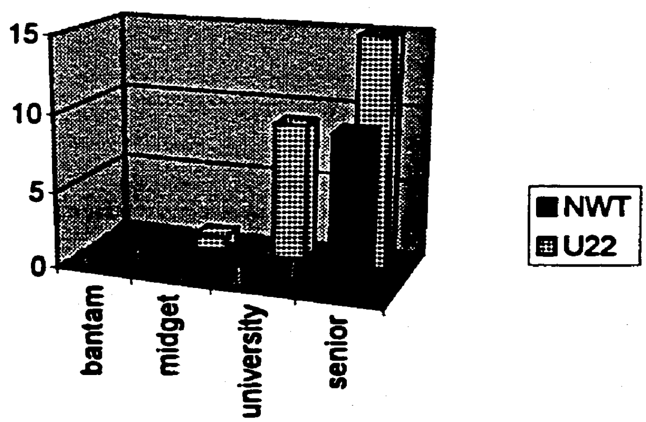


Figure 4-11 Highest age level the players on the NWT and U22 had competed at.

The next question on the survey related to the highest level of women's hockey the participants had played (eg. provincial, national, international, etc.) Survey data results indicated that 42% of the NWT have played at the international level. Figure 4-12 illustrates that the lowest level of hockey played by players on either team is AAA.

Question five asked the players to comment on the highest level of championship hockey they had participated in. Over half of the players from each of the two National teams have competed in a championship at the national or international level (Figure 4-13).

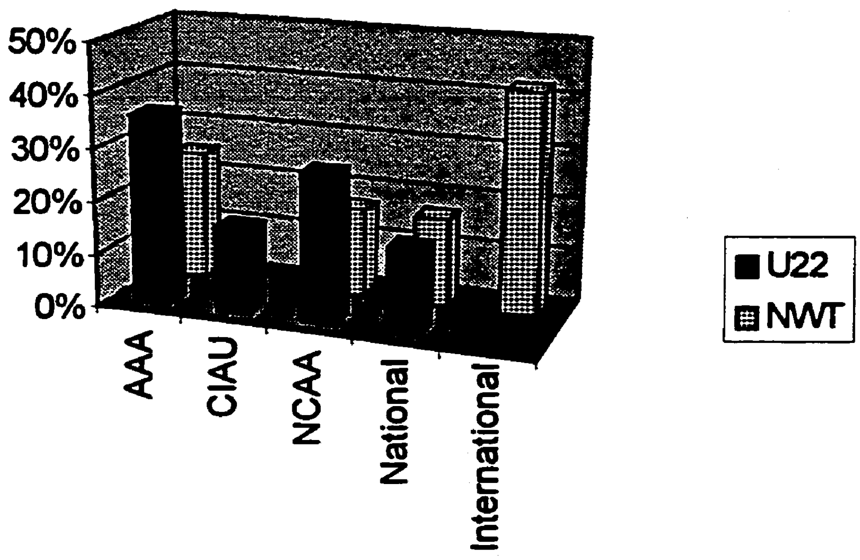


Figure 4-12 The highest level of women's hockey that players from the NWT and the U22 team had competed in.

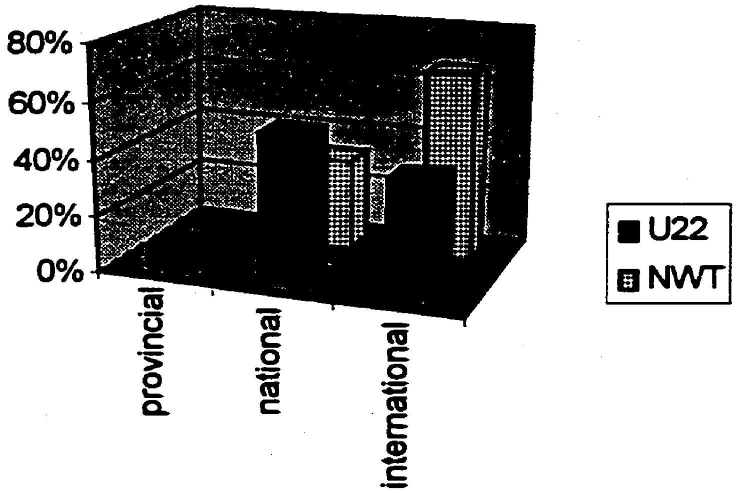


Figure 4-13 Highest level of championship that the participants of this study had competed in.

The next question related to the main difference between men's and women's hockey. The players stated that the main difference between men's and women's hockey is harder and more accurate shots, faster passes and better skating by the male players. The players from the NWT believed that the most significant difference between the two sports was harder shots in the game of men's hockey (Figure 4-14).

Question eight of the survey asked the players if they believed a female hockey player could shoot and pass the puck with the same velocity as a male player. One hundred percent of the NWT did not believe females could shoot and pass with the same velocity as males. According to the U22 team members, 88% agreed with the NWT and 8% disagreed. The other 4% of the U22 team were undecided. Table 4-4 states the reasons for this difference according to the two women's national teams.

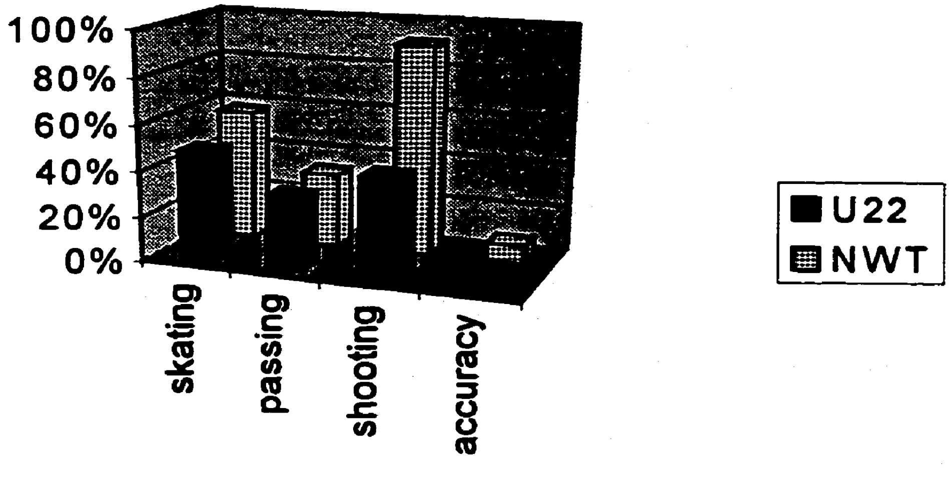


Figure 4-14 The most significant differences between male and female hockey players according to the U22 and NWT players.

The next question related to the velocity at which male and female hockey players can raise the puck off the ice (Table 4-4). Ninety-two percent of the NWT, and 72% of the U22 players did not feel female players can raise the puck with the same velocity or accuracy as male players. The reasons for the differences between male and female players, as outlined by the two national teams, are also listed in Table 4-4.

The next question asked the players how they would feel if female hockey adopted a lighter puck. Forty-two percent of the NWT thought it would be a "good idea" while half of the respondents thought it was "worth a try" and the others simply "didn't care". The results of the of the U22 team questionnaires are compared to the responses of the NWT team in figure 4-15.

Table 4-4 Reasons for skill differences between the genders in the sport of ice hockey according to the NWT and U22 teams.

	males stronger		physical size		males skate faster	
	NWT	U22	NWT	U22	NWT	U22
Most significant reasons why female players do not shoot and pass the puck with the same velociy as male players.	100%	88%	1%	12%		4%
Most significant reasons why female players do not raise the puck with the same velocity and accuracy as male players.	92%	76%	8%		8%	

Note. Players could select more than one response for each question.

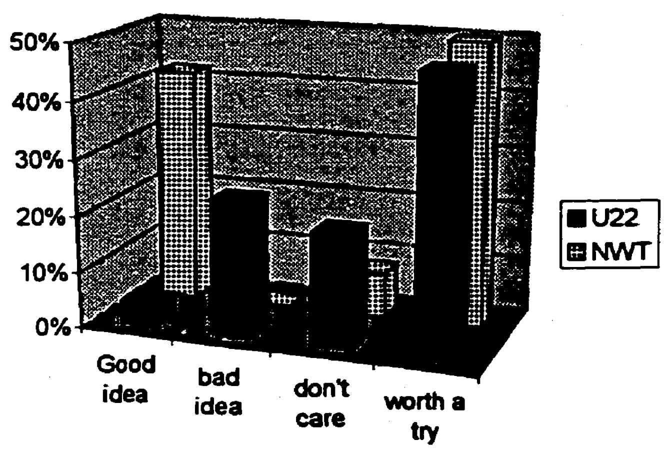


Figure 4-15 How both teams felt about adopting a lighter puck into women's hockey.

The next two questions asked the players if they were willing to try a light weight puck in practice and/or in a game. All 12 members of the NWT were willing to try a lighter puck in a practice and a game. The majority of players from the U22 team would try the lighter pucks in a practice and a game (Table 4-5).

Table 4-5 Willingness to experiment with light weight pucks and the impact on player development.

	yes		no		maybe	
	NWT	U22	NWT	U22	NWT	U22
Would you be willing to experiment with a lighter puck in practice?	100%	96%		4%		
Would you be willing to experiment with a lighter puck in a game?	100%	76%		16%		8%
Do you think a lighter puck would enhance the development of shooting and passing skills in women's hockey?	92%	52%		36%	8%	8%

The next question asked the players about the advantages of using a lighter puck. The most commonly selected advantages of using a lighter puck in the game of women's hockey, according to the NWT and U22 team, are a faster game, faster shots and faster passes (Figure 4-16).

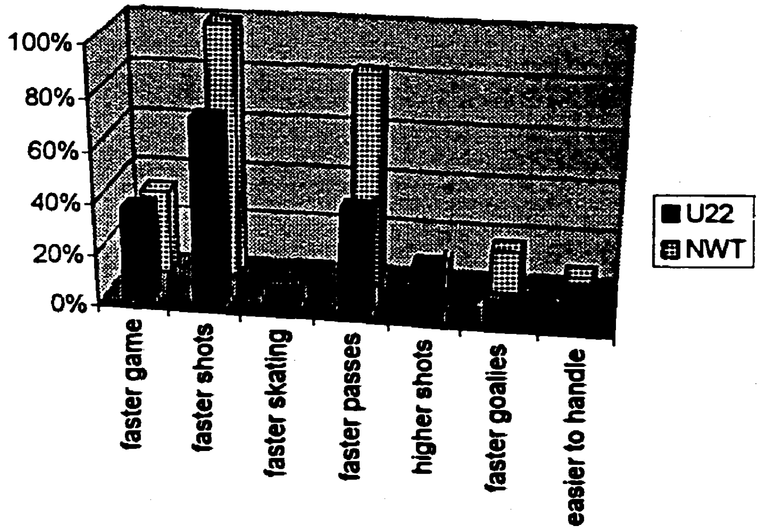


Figure 4-16 Possible advantages of adopting a lighter puck into women's hockey according to the NWT and U22 players.

Question 15 asked the players to state what they felt would be the greatest disadvantage of a lighter puck in women's hockey. The majority of the participants from both teams felt that the greatest disadvantage of a lighter puck in women's hockey would be that the puck was "too light and difficult to handle" (Figure 4-17). The players felt another disadvantage was that the shots may be too high for goalies.

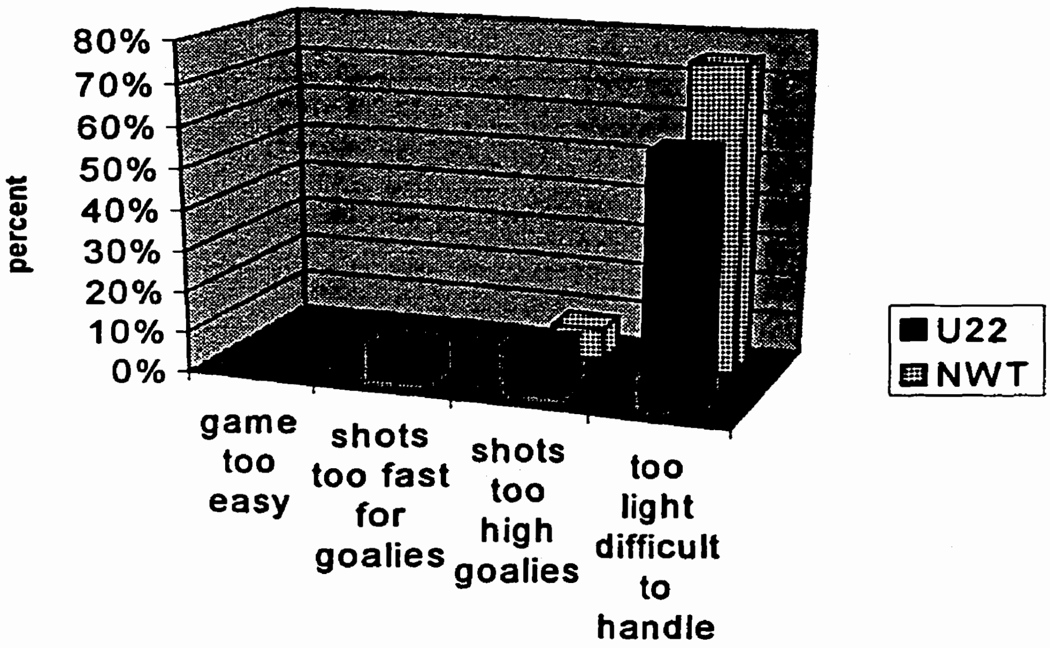


Figure 4-17 The disadvantages of a lighter puck in women's hockey, according to the NWT and the U22 players.

The second last question of the survey asked players how they felt women's hockey would be viewed if a lighter puck were adopted. A greater percentage of players from the U22 team felt that the game of women's hockey would be viewed negatively if a lighter puck were adopted into the sport. Players felt that the game may be viewed as "a game for the weaker sex", "a game too easy", or "not real hockey" (Figure 4-18).

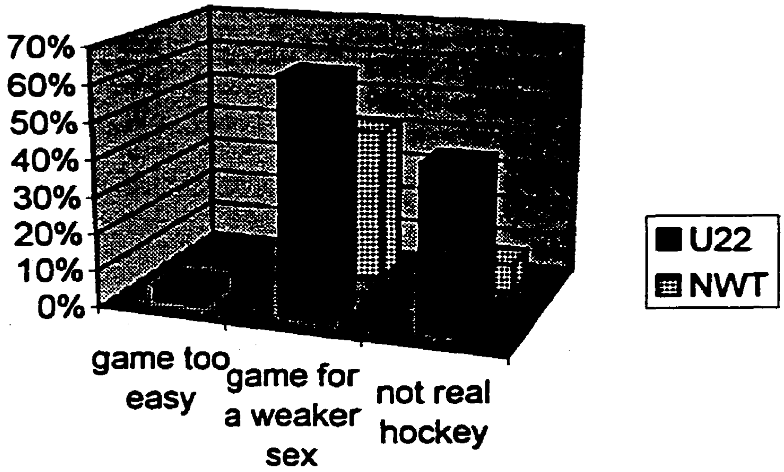


Figure 4-18 How players from the NWT and U22 team felt women's hockey would be viewed if a lighter puck were adopted.

The final question of the pre-test survey asked players to provide additional individual comments and concerns about the use of light weight pucks in women's hockey. Some of the most common responses were that "there is no reason to change as the players are doing fine with the regulation puck" and that "a lighter puck would give women the persona of being weak and unable to play traditional hockey". Additional results are included in Appendix H.

Post –test surveys

The post-test surveys were completed by the players from both teams immediately after their respective ice sessions. The first question of the post-test survey related to whether or not the players from the NWT and U22 team preferred the lighter pucks to the regulation puck. Prior to using the lighter pucks, 67% of the NWT felt they would enjoy playing with the lighter pucks while 56% percent of the U22 players agreed (Table 4-5). Individual responses to each of the survey questions are included in Appendix I.

After using the lighter pucks, 58% of the NWT preferred the new object, one player did not, and four players or 33% of the participants, were undecided (Table 4-5). The next question asked the participants if it took a long time to adjust to the lighter pucks. According to the NWT, the lighter puck did not take long to adjust to (67%), in the U22 group 36% of the players stated it did not take long to adjust to the new puck whereas the other 52% disagreed (Table 4-6).

Table 4-6 Responses of the NWT and U22 team on the preference of a lighter puck and the time it took to adjust to the new projectiles.

	NWT					
Question	yes	%	no	%	unde-cided	%
1. Did you think that you would prefer playing with the lighter pucks before this this ice session?	8	67	4	33		
2. Do you prefer the lighter pucks now?	7	58	1	8	4	33
3. Did it take long to adjust to the lighter pucks?			8	67	4	33
	U22					
1. Did you think that you would prefer playing with the lighter pucks before this this ice session?	14	56	8	32	2	12
2. Do you prefer the lighter pucks now?	8	32	15	60	1	6
3. Did it take long to adjust to the lighter pucks?	13	52	9	36	2	8

Questions five through 13 required the participants to respond to statements using a seven point scale. The responses ranged from strongly disagree, disagree, slightly disagree and no difference to slightly agree, agree and strongly agree. The responses received a score of one to seven. Strongly disagree received a score of one and strongly agree received a score of seven. If no difference was chosen as a response the players received a score of four. The mean scores and standard deviations for each of the teams are included in Table 4-7. It should be noted that the NWT and the U22 had different experiences with the lighter pucks, therefore the NWT did not respond to all the questions as they did not perform certain skills referred to in the questions.

The NWT agreed with the statements that the lighter pucks: were easier to stickhandle, could be shot with a greater velocity, could be raised off the ice more easily and could be released more quickly. However, the NWT did not believe shots with the lighter pucks were more accurate than shots with the regulation pucks.

The U22 players agreed with the statements that lighter pucks: could be shot with a greater velocity, could be raised off the ice more easily, could be released more quickly, and could be passed with a greater velocity. Players from the U22 disagreed with the statements that lighter pucks: were easier to stickhandle, could be shot or passed more accurately, could be received more easily, enabled players to perform breakaways with greater ease.

Table 4-7 Responses of the NWT and the U22 on the effect of lighter pucks on skill performance in women's hockey.

	U 22		NW T	
	M	SD	M	SD
5. The lighter pucks were easier to stickhandle.	3.3	1.9	5.2	0.5
6. The lighter pucks could be shot with a greater velocity.	6.2	0.8	5.9	1.7
7. The lighter pucks could be raised off the ice more easily.	6.2	1	6	1.4
8. Shots with the lighter pucks are more accurate.	4.1	1.5	4.1	1.8
9. The lighter pucks could be released more quickly.	5.2	1	6.1	0.8
10. The lighter pucks could be passed with a greater velocity.	5	1.6	N/A	
11. Passes with the lighter puck were more accurate.	3	1.4	N/A	
12. The lighter pucks could be received more easily.	2.9	1.4	N/A	
13. Breakaways were easier to perform with the lighter pucks.	3.7	1.1	N/A	

Question 14 referred to the difference in feel between the four pucks of different weights. Ninety-two percent of the NWT felt there was a difference in feel between the lighter pucks and the regulation puck, 96% of the U22 team agreed. Sixty-seven percent of the players felt the greatest difference in feel was when the players executed skills with the 4.5 oz puck, another 25% felt the greatest difference with the 5.0 oz puck. The U22 team felt the greatest difference in feel was when the players used the 4.5 oz (84%), 5.0 oz (8%) and 5.5 oz (4%) pucks.

The next question of the post – test survey asked players if the lighter pucks would enhance the development of shooting and passing skills in women's hockey. The majority of the NWT (92%) stated that a lighter puck would enhance the development of shooting and passing skills in women's hockey, eight percent of the players were undecided. The responses of the U22 were significantly different as only 56% of the players felt a lighter puck would enhance the development of shooting and passing skill in women's hockey, 44% of the players disagreed.

When asked to list the advantages of a lighter puck, members of both teams stated that the greatest advantages of a lighter puck would be faster shots and faster passes, as well as, faster game, faster skating, higher shots and faster goalies (Figure 4-19).

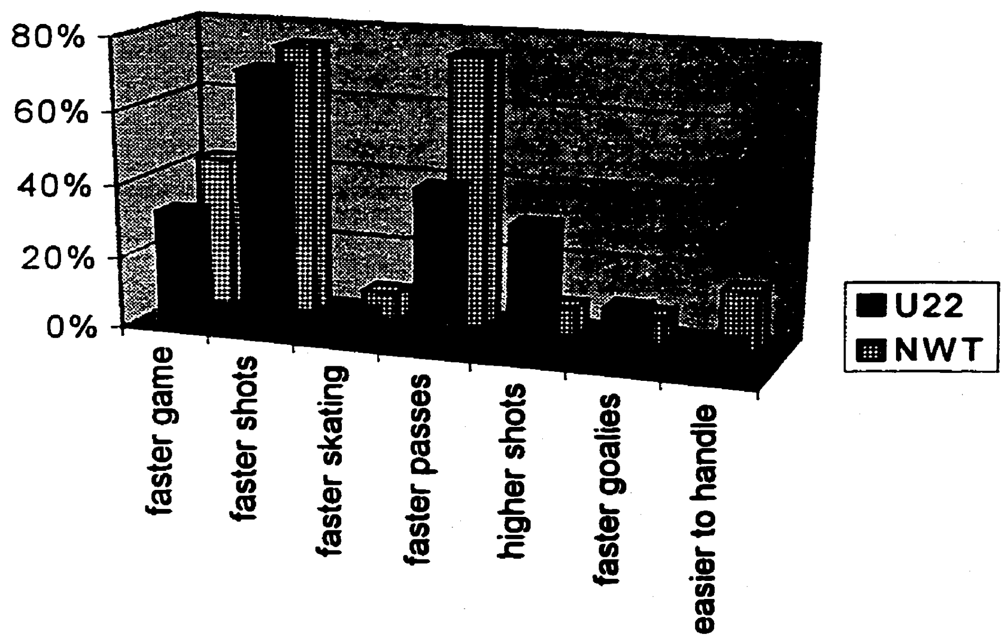


Figure 4-19 Advantages of a lighter puck according to members of the NWT and the U22 team.

The players were then asked to list the disadvantages of a lighter puck. The majority of players from both teams felt that the greatest disadvantage of a lighter puck was that is was too light and difficult to handle. Participants stated that a lighter puck may result in a game that was too easy, shots would be too fast for goalies and that the shots may be too high for goalies (Figure 4-20).

Question 18 of the survey referred to which of the three light weight pucks the participants preferred if a lighter puck was to be adopted. Figure 4-21 suggests that the NWT would prefer the 5.0 oz puck if a lighter puck was to be adopted into women's hockey, 40 % of the U22 players agreed.

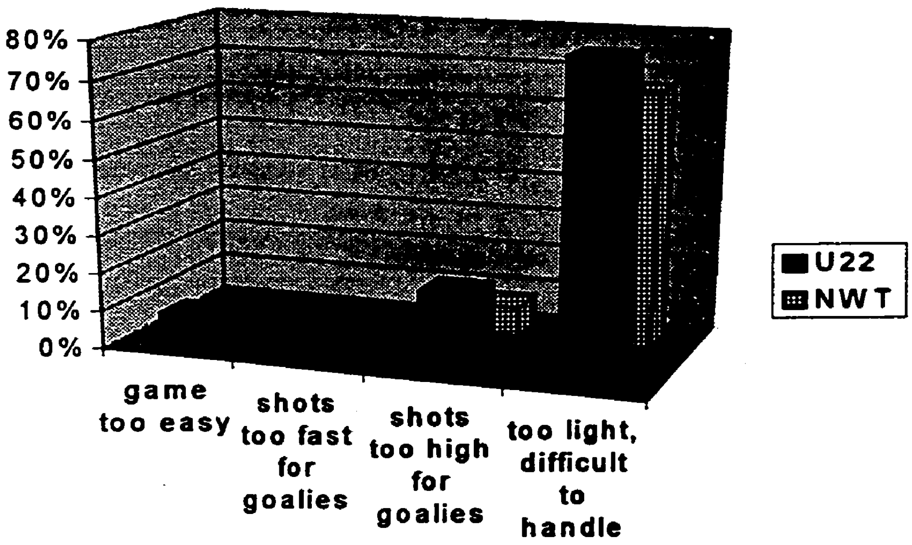


Figure 4-20 Disadvantages of adopting a lighter puck into women's hockey according to the NWT and the U22 team.

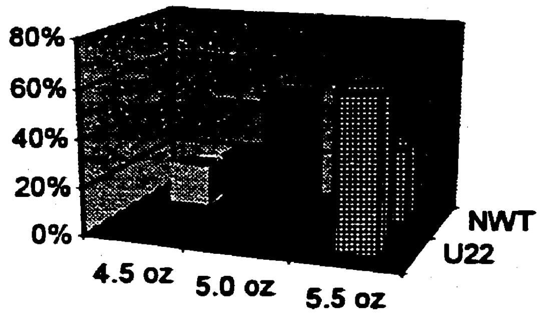


Figure 4-21 Puck weight players would prefer if a lighter puck was adopted into women's hockey.

Question 19 of the survey related to how women's hockey would be viewed if a lighter puck were adopted into the sport of women's hockey. Fifty-eight percent of the NWT believed that a change to a lighter puck in women's hockey would be viewed as a revolution in women's hockey and 50% believed it would be an adaptation that would enhance the women's game. The U22 group expressed much different responses as 74% of the players felt it would be viewed as "a game for the weaker sex", and 48% believed it would be viewed as "not real hockey" (Figure 4-22).

The final question of the post – test survey asked players to provide additional individual comments and concerns about the use of light weight pucks in women's hockey in the last question of the post-test survey. The most commonly stated comments and concerns were that the lighter puck was too bouncy and difficult to control. Other comments were that it was a great idea, women's hockey needs a lighter puck and that a lighter puck would be great for younger and developing players. Results are included in Appendix L.

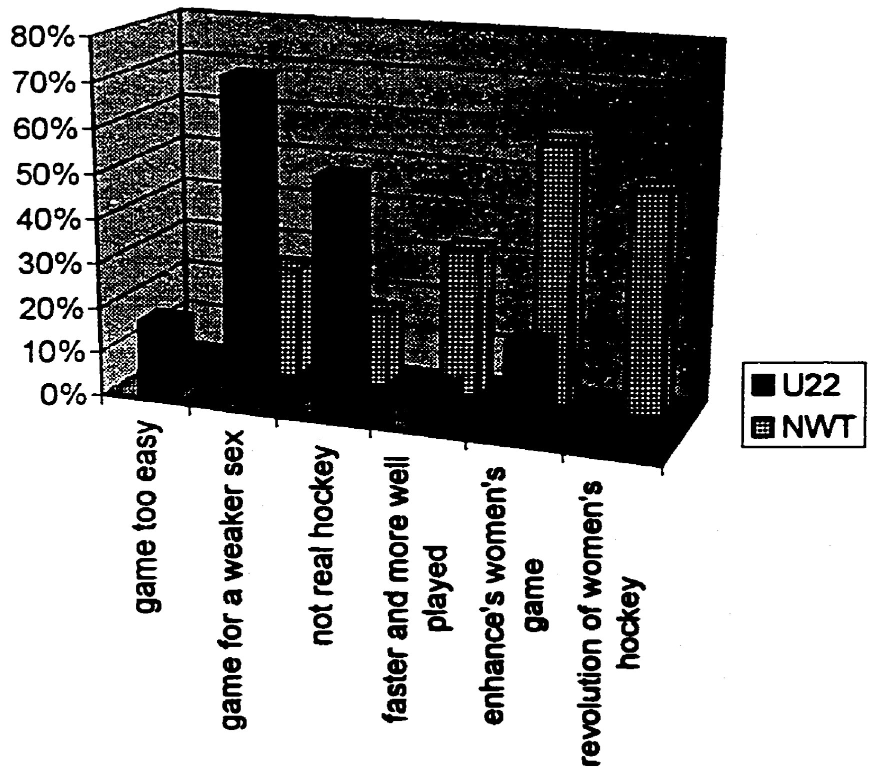


Figure 4-22 How players feel women's hockey would be viewed if a lighter puck were adopted.

CHAPTER 5

DISCUSSION

The purpose of this study was to determine the effects of a light weight puck on the biomechanics of the wrist shot, as well as the puck velocity and accuracy of the wrist shot among female hockey players. A subproblem of the study was to determine if any difference exists in the stickhandling and passing skills of female hockey players when using a light weight puck. An additional subproblem was to gather pre and post attitudinal data of elite female hockey players using lighter pucks to determine if there was a difference in opinion between age groups on adopting a lighter puck and if the players supported the change.

It was the researcher's intent to design an interdisciplinary study that would encompass the effects of a light weight puck on the game of women's hockey both technically and tactically, as well, to investigate the impact a light weight puck would have on players through the use of attitudinal data. In order to understand the overall effects of the lighter pucks (4.5 oz, 5.0 oz, 5.5 oz) three different tools were used including 3-D film analysis of the biomechanics of the wrist shot, hockey skill tests and questionnaire surveys.

The results of this study supported the null hypothesis that the biomechanics of the wrist shot would not change when executing a wrist shot with three light weight pucks. Shooting, puckhandling and goaltending skills of the female hockey players did not differ significantly when using the light weight pucks, however, passing skill test results indicated there was a significant difference in passing time between the 4.5 oz puck and the other three puck weights. Light weight pucks did not increase the velocity of the players' wrist shots and did support the hypothesis that an increase in puck velocity would not be evident. The results of the attitudinal data rejected the hypothesis that there would be no difference in opinion between the age groups. Three questions of the post – test were designed to investigate the participants attitudes towards the adoption of a lighter puck in women's hockey. Fifty-eight and 32 percent of the NWT and the U22 team, respectively, preferred the lighter pucks after experiencing the new projectiles. In addition, 92% of the NWT and 56% of the U22 team felt the lighter pucks would enhance the development of shooting and passing skills in women's hockey. However, there was not an overwhelming majority of players that felt women's hockey would be viewed positively if a lighter puck were adopted. Based on these findings it is difficult to conclude if the NWT and the U22 would support the adoption of a lighter puck into women's ice hockey.

Wrist Shot Analysis

Since only 12 subjects participated in the wrist shot filming, it was difficult to obtain significant results for any of the tests. However, a few patterns were evident in the data that suggested a lighter puck may affect several of the variables calculated in this study. Despite the fact that the 12 participants were elite female hockey players, there was still a broad range of skill in the variables recorded. This did make the data more generalizable as the variability in the data is representative of less skilled teams.

The results of the puck velocities are address the concerns of the CHA Board of Director's as the data support the opinions expressed in the surveys that the female players felt the lighter pucks could be shot and passed with a greater velocity than the regulation pucks. Although not significant, the results suggested there was an immediate increase in shot velocity despite the fact that most of the subjects were using the lighter pucks for the first time.

There are few studies in the literature that have investigated the velocity of hockey shots. This is a surprising finding since ice hockey is one of the most popular team sports in Canada. The few studies that were located were all published over 20 years ago, again indicating the lack of interest in ice hockey skill research. It may be that the ice hockey coaching establishment is comprised primarily of coaches who lack interest and confidence in formal research. However, this lack of research in ice hockey has limited the ability of coaches to critically analyze skill performance of their players using sound scientific findings.

The female players in the current study performed the standing wrist shot with a velocity of 43.94 mph ● 3.96 (19.53m/s ±1.76 m/s) mph when using the 6.0 oz puck and 46.22 mph ● 2.84 mph (20.54 m/s ± 1.26 m/s) with the 4.5 oz puck (See Table 4-1).

A study by Alexander et al. (1963), analyzed the velocity of the standing wrist and slap shots, as well as, the skating wrist and slap shots. Velocities were calculated with a ballistic pendulum and 30 subjects, representing four different teams, participated in the study. All subjects were male and the skill level of the players ranged from professional to amateur and the university level. The velocities of the standing wrist shot with the regulation puck were compared to the velocities obtained in the wrist shots filmed of the female hockey players. The most skilled male team (n = 11) demonstrated an average velocity of 63.1 mph ± 5.9 mph (28.22 m/s ± 1.9m/s), the two amateur teams (n = 7, n = 6) had velocities of 62.4 mph ± 4.3 mph (27.3 m/s ± 1.87 m/s) and 58.7 mph

± 8.0 mph (25.52 ●3.48), respectively, while the university team members achieved an average puck velocity of 54.3 mph ● 5.3 mph (23.60 m/s ●2.30 m/s) for the standing wrist shot. The puck velocities are similar to a study performed by Naud & Holt (1975) in which two former professional hockey players recorded an average, standing wrist shot velocity, of 55 mph ± 1mph (23.91 m/s ●0.43 m/s). Unlike the study by Alexander et al. (1963) a cinematographic analysis was used to calculate the velocities of the 6.0 oz puck.

Dore and Roy (1979) performed a study that calculated the puck velocity of nine subjects of various skill levels; Junior A, B, Senior and University students specializing in hockey. The average puck velocity for the nine participants, with a regulation, 6.0 oz puck was 60.68 mph ± 3.06 (26.38 m/s ± 1.33 m/s) mph while executing the standing wrist shot. Photoelectric cells were used to accurately measure the velocity of the puck and velocities were similar and comparable to the previous studies mentioned. Caution should be exercised when comparing the results of the current study with the previous studies as several different methods were used for calculating puck velocities. It is evident that the elite female hockey players in the current study could not shoot the puck with same velocity as male players of a similar skill level. If the goal of the Canadian Hockey Association is to have female players shoot the puck with a higher velocity, similar to that of male players, the current study suggests (although the results were not significant) that a lighter puck could allow female players to achieve higher velocities and possibly narrow the velocity gap between genders.

Turning to angular displacement of the stick blade this study found no significant difference between the results of the four puck weights. According to Dore and Roy (1976) only one previous study by Romechevsky (1974) had dealt with this subject. The current researcher suggests that angular displacement of the stick blade could represent the amount of pronation occurring at the wrist joint. It is possible that a small degree of angular displacement of the stick blade is a result of medial rotation of the shoulder. However, because of the position of the hands on the stick and the extended elbow of the bottom arm, it is more likely that angular displacement of the stick blade is a result of forearm pronation. More research has to be done in this area with players who are not required to wear protective gloves or a track suit to confirm that angular displacement of the stick blade is a result of pronation of the forearm. The absence of the track suit and the protective equipment would allow the researcher to analyze the movements at the forearm and shoulder joints more accurately. Additionally, the movement at the wrist joint and the velocity at which it occurs may be important in determining the velocity of the wrist shot. Unfortunately, there is not any published research to support this assumption and during the course of this study, it was just that, an assumption.

A study by Hayes (1965) incorrectly states that wrist pronation is occurring at the wrist joint in the wrist shot and is a major movement in the joint, based on film analysis. However, the angular displacement and velocity of wrist pronation were not recorded in the study. Wrist pronation is difficult to measure because it is a rotational movement of the forearm and not the wrist joint. The head of the radius rotates about the ulna in the annular ligament at the elbow joint and the two bones cross as the wrist moves from a supinated position to a pronated position. Unlike flexion of the wrist or shoulder joint, it is difficult and inaccurate to landmark an axis about which forearm rotation occurs as the axis is the long axis through the lower arm that passes through the radio – ulnar joints. Additionally, medial or lateral rotation of the shoulder may be mistaken for pronation or supination of the forearm, as it is difficult to distinguish between these movements if pronation/supination is estimated by analyzing the position of the hand. The current researcher believed that wrist shot pronation was an important variable because pronation of the wrist is a major movement in the wrist shot, and there is no published research on the kinetics and kinematics of this movement. Because pronation is such a difficult movement to analyze, it was assumed that stick blade angular displacement was directly correlated with forearm pronation.

Based on their previous studies Dore and Roy (1979) state that the wrist joint is more active in the wrist shot than the slap shot. Only flexion of the wrist was recorded but the authors stated that the wrist of the bottom hand on the stick, flexed up to 39 degrees in total and reached an angular velocity of 570 degrees/s at impact with the puck. Combined with the elbow joint, it was suggested that the wrist joint had a relative contribution of 20-25% to the velocity of a shot. Unfortunately, Dore and Roy (1979) did not investigate wrist pronation. It is interesting to note that the maximum velocity of wrist flexion occurred within .05 s of puck release, this is consistent with the findings of the current study in which maximum angular velocity of the stick blade occurred within .02 - .07 seconds of puck release for each subject (See Table 4-3).

It was difficult to analyze the results of angular displacement and velocity of the hips and shoulders as the film data was inconsistent. There was not a significant difference between the angular displacement and velocities of the hips and shoulders with the four puck weights. One of the reasons for this is that the players were instructed by the Canadian Hockey Association to wear the team tracksuit during filming. It is mostly black and was difficult to accurately locate joint centers because the midsection of the body and the extremities were the same color. More accurate digitization would have been possible if the subjects had worn tight fitting clothing of contrasting colors in the trunk and limbs. Additionally, the players had to wear hockey gloves for insurance and injury prevention purposes. The protective equipment decreased the accuracy of wrist joint center identification during the digitization process. Due to the short amount of time (one week) the players spent at the selection camp, team officials did not want the players to jeopardize their chances of making the team by getting injured during the testing. As well, the insurance policy that covers the Canadian National Team requires players to wear helmets and gloves on the ice at all times.

A study by Dore and Roy (1979) on males investigated the angular velocity of the trunk and shoulder segments and the time at which the rotations occurred in the execution of the skill. Unfortunately, the study did not outline the methods used to calculate trunk and shoulder angular displacement and angular velocities. The results suggested that the trunk rotated prior to the shoulders, consistent with "the principle of continuity of joint forces".

The theory states that " In the execution of various types of shots, the rotation of the trunk occurs an instant before that of the shoulder and the other more distal joints. Because this sequence of actions must be executed very rapidly, the total time is short, and the timing of movement from one segment to another should occur without interruption. The movement should be rapid and continuous. If there is interruption, or if the action does not proceed in the right order, the total amount of force will be reduced" (Dore and Roy, 1976, p. 61).

It was interesting to note that one of the shooters with the greatest velocity demonstrated the same sequence of rotation as in the study by Dore and Roy (1976). Maximum velocity of the hips occurred just prior to maximum angular velocity of the shoulders followed by maximum angular velocity of the stick blade. The movements also occurred very rapidly as the maximum velocity values of each body segment occurred 0.02 s apart, consistent with the study by Dore and Roy (1976). Unfortunately, in the current study, few of the participants displayed a similar sequence of body segment movements. It is possible that inaccuracies in the digitization process affected the timing results of segment rotation and other wrist shot variables.

There are very few research articles describing the linear displacement of the center of gravity of the player during execution of the stationary wrist shot. However, the study by Alexander et al. (1963) stated that the skating wrist shot resulted in a greater velocity than the stationary wrist shot in each of the four age groups. It can be concluded from this study that the greater the linear displacement of the center of gravity, the greater the velocity of the shot because the linear velocity of the center of gravity is added to the final linear velocity of the puck. Individual linear displacement data in the current study supports this theory as the player with the lowest wrist shot velocity also demonstrated the least amount of linear displacement of their center of gravity with each of the four puck weights. However, the four shots with the greatest linear velocity did not demonstrate the greatest linear displacement of the center of gravity for all four puck weights.

It is important to note that the players with the greatest wrist shot velocity demonstrated much greater angular displacements and velocities of the hip, shoulder, and stick blade, as well as linear displacement of their center of gravity than the players with the slowest shots. This suggested that the highly skilled shoulders are able to transfer the high velocities of their body segments and displacement of their center of gravity to the puck. Because the timing of these movements did not differ between the highly skilled and less skilled shooters it is evident that if the less skilled shooters are able to produce greater rotational velocities of their hip, shoulder and stick blade, as well as linear displacement of their center of gravity their shot velocity will increase. Players wanting to improve the velocity of their shots should concentrate on increasing the velocity of their body segments to improve the velocity of their shot. Further research must be done in this area to determine the most significant differences between skilled and less skilled shooters. Once these variables are determined, coaches and players can modify their training to improve these variables and eventually increase shot velocity.

In conclusion, the current study did not reveal any significant difference in the variables investigated for the standing wrist shot performed with pucks of different weights. Comparison of the variables investigated in this study to those reported in other studies is limited as the majority of studies performed (Alexander et al., 1963, Dore & Roy, 1976, Dore and Roy, 1979) do not include a complete kinetic and kinematic analysis of the hockey wrist shot. More importantly, there are no studies that have focused on or even included female hockey players. The present study suggests that female hockey players do not shoot the puck with the same velocity as their male counterparts but there is no research presently available that attempts to investigate the reasons for this difference. The current study is unique in that there hasn't been any prior studies on female hockey players executing a wrist shot or the angular displacement and velocity of the forearm, of the bottom hand on the hockey stick. This lack of research on both male and female hockey is surprising and disappointing considering that hockey is one of the most popular team sports in Canada.

Hockey Skill Tests

The current study included five hockey skill tests that assessed the skill performance of female hockey players with pucks of four different weights. The players were required to perform stickhandling, passing, shooting and goaltending skills throughout the study. Skill tests were important to this study as the drills attempted to evaluate the effects of a light puck in game-like situations. Four of the five skill tests did not yield significantly different results between the four puck weights. In the Passing skill test, the participants attained significantly slower times when using the 4.5 oz puck as compared to the 5.0, 5.5 and 6.0 oz pucks. The results suggested that the players could performed more poorly in the Passing skill test when the lightest puck was used.

Several other studies have examined rule and equipment changes for females playing sports originally designed for males. A similar report by Husak et al. (1984) included five different studies (Phase 1, 2, 3, 4 and 5) that attempted to investigate the influence of the smaller women's basketball on performance and attitude. Of the studies in the literature, the study by Husak et al. (1984) is the most extensive as several aspects of women's basketball were investigated including player performance with the smaller ball in skill tests and the attitudes of the players towards the use of a smaller ball. Phase 1 of the study included six basketball skill tests (Dribble, Speed Pass, Baseball Pass, Foul Shot percentage, Side Shot score and Key Shot score) with high school athletes ($n = 92$) and nonathletes ($n = 100$) and college athletes ($n = 94$) and nonathletes ($n = 77$), with the regulation and smaller, lighter ball. Participants had the opportunity to practice with the smaller, lighter ball for ten minutes. A significance level of $p < .10$ was established and the university athletes demonstrated a significant difference with the smaller ball in the

Speed Pass drill. Results for the high school and university nonathletes showed significant differences for the smaller, lighter ball in the Speed pass and Baseball pass drills and the Dribble, Speed pass, Baseball pass and Side Shot score, respectively. The high school athletes produced a significant difference in performance with the larger ball in the Dribble, Baseball pass, Foul Shot and Key Shot drills.

The results of Phase 1 of the study by Husak et al. (1984) are not consistent with the findings of the current study that only reported significant differences in the Passing skill test (See Table 4-6). Possible reasons for this finding are that only elite female players were used in the current study and not nonathletes, the sample size for the current study was much smaller and the studies involved different sports. Another reason is that the new projectile in the basketball study was a different size and weight (17.5 – 19.5 oz or 496.13 –552.83 g, 28.5 – 29 inches or 72.39 – 73.66 cm in circumference) than the regulation ball (20 – 22 oz or 567 – 623.7 g, 29.5 – 30 inches or 74.93 – 76.2 cm in circumference) whereas the lighter pucks (4.5 oz, 5.0 oz , 5.5 oz) were the same size (7.5 cm in diameter and a height of 2.5 cm) but a different weight than the regulation disc (6.0 oz). Additionally, the difference in weight between the two basketballs may have been greater than the pucks depending on the exact weight of the balls.

Phase 2 of the study by Husak et al. (1984) involved eight skill tests and surveys of 335 high school varsity players attending a summer camp. The skill tests included timed layups, foul shots, side shots, key shots, a baseball pass at a target, a baseball pass for distance, speed pass against a wall and a dribble test. Participants practiced with the lighter balls for four days before being tested with the new, lighter, smaller basketball and the regulation ball. Ball sizes and weights were the same as in Phase 1 of the study.

Results with the small ball were significantly different than the regulation ball for three of the eight skill tests, the Timed Layup, the Speed Pass, and the Baseball pass for distance. These results were not in agreement with the current study examining hockey pucks that reported a significant difference in only the Passing skill test. Reasons for the difference may be a smaller sample size in the hockey skill tests, different sports, greater difference in weight between the basketballs than the pucks, a difference in size as well as weight with the basketballs, and the amount of time the subjects had to practice with the new projectiles. Hockey is unique compared to basketball in that the players handle and shoot the projectile with an implement and not their bare hands. It is difficult to compare tests from two sports that do not utilize similar equipment. The basketball skill tests that were most similar to the hockey skill tests were the Speed Pass and Dribble tests, similar to the Passing test and Stickhandling test of the current study. None of these tests scores were found to be significantly different when using altered equipment.

A study by Bedingfield and Skleryk (1985) used five skill tests to evaluate the effect of basketball size and weight on the skill performance of intercollegiate basketball players. The study included 71 female and 35 male CIAU basketball players. For the purpose of this study only the results of the female players were reported. Four of the skill tests (Lay-up, Side Shot, Speed Pass, and Dribble) were adopted from the American Association of Health, Physical Education and Recreation AAPHER Basketball Skills Test Manual for Girls (1966) and were used in the study by Husak et al. (1984). The other test, the Figure 8 was a skill test from a study by Dailey and Harris (1984). Three basketballs were used in the study, a regulation size basketball (Ball A), Ball B (average circumference of 28.5 inches or 72.39 cm, 18.0 oz or 510.3 g) and Ball C that was the same size as Ball B and the same weight as Ball A (20.5 oz or 581.18 g). Subjects received a practice period to familiarize themselves with the new basketballs. Significantly different results were evident in the Dribbling and Speed Passing drills. Players demonstrated the fastest time for the Dribbling skill test with the regulation ball and were slowest with the ball of smaller size but equal weight. Ten chest passes in the Speed Pass skill test were completed in the fastest time with the smaller and lighter ball and in the slowest time with the smaller ball of equal weight to the regulation ball. The results of the study by Bedingfield and Skleryk (1985) disagree with the present study and studies by Dailey and Harris (1984) and Pitts (1985). Participants in the study by Dailey and Harris (1984) demonstrated significantly different scores in the Side Shot, the Speed Pass and the Figure 8 skill tests. Significant differences were not evident in the Dribbling test. In the study by Pitts (1985), performance was significantly improved in the Side Shot, the Layup, the Speed Pass, and the Dribble skill tests.

The current study, however, did not demonstrate a significant difference in four of the five skill tests. Again, the different results may be due to the following: there was a larger sample size in the basketball studies, the two sports incorporate different equipment, the difference in projectile weight was greater in the basketball studies, and the size of the ball was altered, not just the weight, as in the hockey study. The surveys suggested that players had difficulty in handling the lightest, 4.5 oz puck. The results of the skill test support this theory as the Passing test was the only test that demonstrated a significant difference between puck weights. Passing tests with the 4.5 oz puck had significantly greater times than the other three pucks, suggesting players had difficulty passing and receiving the lightest projectile. The reasons for that may be due to the fact that the Passing skill test involved two players, one player that was being timed and the other player that returned the passes. The investigator felt that two players were needed as it was more game-like than passing the puck against the boards, or as in basketball and lacrosse, the wall. In Hodges Lacrosse test, the Wall Volley test required players to stand behind a designated line and throw the ball above a line on the wall and attempt to catch it on the return. The test lasted 60 seconds and the goal of the test was to pass and catch the ball as many times as possible in one minute (Collins and Hodges, 1978). This test would be more reliable than using an additional player as the wall is a constant and the ball will rebound off the wall with a velocity consistent with the velocity the ball was travelling, depending on the coefficient of restitution.

The problem with using this test in ice hockey is that the coefficient of restitution of the puck is too low and it will not rebound off the boards with a high enough velocity to evaluate the receiving skills of the player. Due to the structure of the boards and the ice it would be very difficult for the player to keep the puck flat on the ice, without it bouncing or flipping up on end. This is unlike the basketball or lacrosse test in which the ball travels through the air and maintains its line of direction when it rebounds off the flat wall. One other reason the Passing skill test may have yielded significant differences between the 4.5 oz puck and the other three puck weights is that the drill involved receiving skills that were not investigated in the other skill tests. It is important that a player can shoot and pass the puck with a greater velocity but a faster pass is not useful if the players cannot accept the pass. It may have been difficult for the players to receive the passes with the lightest puck because the 4.5 oz puck is only 75% of the weight of the regulation puck and demonstrated the greatest increase in velocity of the wrist shot.

Therefore, it is safe to assume that the players passed the 4.5 oz puck with the greatest velocity during the passing skill test.

Additionally, the 6.0 oz puck had a greater inertia and is more resistant to a change in motion than a 4.5 oz puck. For example, players stated that the puck bounced off their stick during the passing drills. This was because the 4.5 oz puck has less mass and inertia than the regulation puck, allowing the projectile to bounce off the stick in a different direction more easily and frequently. "The amount of inertia a body possesses is directly proportional to it mass. The more massive an object is, the more it tends to maintain it's current state of motion and the more difficult to disrupt its state" Hall, 1999, p. 63). Newton's first law of motion states that "A body in motion will maintain a state of rest or constant velocity unless acted on by an external force that changes that state" (Hall, 1999, p. 397). In the Passing skill test the stick blade was the external force and it would take less of a force to change the state of velocity of the 4.5 oz puck than the 6.0 oz puck.

Another factor that must be acknowledged when investigating the collision between two bodies, the stick blade and the puck, is linear momentum. Linear Momentum (M) is the product of a body's mass (m) and the velocity (v) the object possesses (Hall, 1999). Linear momentum is a vector that has both magnitude and direction, so force is required to change both magnitude and direction. The greater the momentum of the object the greater the resistance to a change in the state of the object. Despite the fact that the velocity of the 4.5 oz puck was greater than the velocity of the 6.0 oz puck (although not significant), the increase in velocity does not compensate for the difference in mass and the momentum of the regulation puck may still be greater. For example, the mean resultant velocity of the 4.5 oz puck was 20.54 m/s and the mean resultant velocity of the 6.0 oz puck was 19.53 m/s. Therefore, the momentum of the 4.5 oz puck was (mass = .128 kg * 20.54 m/s) equal to 2.63 kg m/s whereas the momentum of the 6.0 oz puck was (mass = .156 kg * 19.53 m/s) equal to 3.05 kg m/s.

Newton's first law also applied to the velocity of the puck weights during the wrist shot filming. The 6.0 oz puck had a greater mass than the 4.5 oz pucks and was more difficult to move from a state of rest. A greater external force had to be applied to the regulation puck to attain the same velocity as the 4.5 oz puck. If the players were exerting maximal force to the puck for each of the puck weights, it would not be possible for the players to achieve the same velocity with a 6.0 oz puck as they did with the 4.5 oz puck. Further, the friction force between a 6.0 oz puck and the ice is greater than the friction force between a 4.5 oz puck and the ice. Friction is the "force acting over the area of contact between two surfaces in the direction opposite that of motion or motion tendency" (Hall, 1999, p. 403). Basically, the greater the friction force the greater force needed to move the object. Friction is the product of the coefficient of static or kinetic friction (μ_s or μ_K, respectively) and the normal reaction force (R) or weight of the body. Static friction is the friction between two bodies that are motionless and kinetic friction is the friction between two bodies that are in motion (Hall, 1999). It can be assumed that the coefficient of friction, static and kinetic, between the four puck weights are equal and does not change, therefore, as the weight of the puck increases, the friction force between the ice and the puck increases proportionately. The heavier the puck, the greater the friction force between the surfaces and the greater the force it takes to achieve a velocity equal to that of a lighter puck. Again, if the players exerted maximal force during execution of the wrist shot for each of the puck weights, it would not be possible to shoot a heavier puck with the same velocity as a lighter puck. Unfortunately, players are not able to exert equal force to the puck each time they perform a wrist shot. This was one reason that elite players from the Canadian National women's team were selected for testing. The players are more consistent (more likely to exert similar, maximal force to the puck for each wrist shot) from one trial to another than less skilled players and it is more likely that the effects of momentum, inertia and friction would affect performance using pucks of different weights.

Comparing shooting tests in the sports of hockey and basketball was somewhat contrived as a hockey player attempts to shoot the puck with a high velocity and accuracy whereas the basketball player is most concerned with accuracy. The "Battery of Ice Hockey Skill Tests" produced by Merrifield and Walford (1969) originally included a shooting test but the test was dropped as the reliability of the test was too low. However, Merrifield and Walford (1969) did state that the reliability of a shooting test could be increased to an acceptable level if a large number of trials and a large number of subjects were incorporated.

The NCAA women's basketball program adopted the smaller, lighter ball in 1984-1985 (Husak et al., 1986) to increase the shooter's range as well as ball handling skills. Women's hockey could adopt the lighter puck to increase the range, velocity and height of players' shots. Presently, the major concern in women's hockey is that the game is played, for the most part, "on the ice" and the majority of the shots are low wrist shots, taken in close to the goal. The Canadian Hockey Association's Board of Directors is hopeful that a lighter puck will allow players to shoot the puck with a greater velocity, take more slap shots, raise the puck more easily, and shoot from further away from the goal. These improvements in skill performance could help to make women's ice hockey an even more exciting game.

The problem with the skill tests performed in this study is that there is a lack of literature in this area for comparison of test results. Many of the tests described in the literature are not described in detail and had to be adapted and adjusted for the purposes of this study. The Accuracy Shoot was similar to that used in the N.H.L. All-Star Skills Competition (Tredree et al, 2000). In comparison, six of the top male shooters in the All Star competition had a mean shooting percentage of 67% with the regulation 6.0 oz puck whereas the six top female players had a slightly higher shooting percentage at 70% (see Appendix H) with the 6.0 oz puck. Although the skill tests in the present study were slightly different than the N.H.L. tests, it is evident that the female players do not lack accuracy with the regulation, 6.0 oz puck.

Although the Breakaway and Rapid Fire skill tests used in this study are similar to those in the N.H.L. Skills Competition (Tregree, 2000), the protocols were not similar enough to compare with the current study. For instance, the Breakaway drill in the All Star competition began at center ice and the players only shot one puck for each trial whereas the players in the current study shot four pucks in each trial and began the drill from the blue line. In the N.H.L. All Star competition Rapid Fire skill test the players had 18 seconds to shoot eight pucks. The shooter received passes from players on each side of the net as the passes alternated from one side of the net to the other. In the current study the players only shot five pucks and did not receive passes from other players, rather, the pucks were placed at designated areas on the ice surface. Additionally, the female players were given ten seconds, as compared to 18 seconds for N.H.L. players, to complete each trial.

Unfortunately, the Puckhandling skill tests in the literature do not provide length of courses or descriptions of courses used in testing. The Passing skill tests, similar to the one used in this study, documented in the literature do not state the distance between players or the protocol for the tests (Hansen et al., 1970). Additionally, there are no available baseline scores for Puckhandling and Passing skill tests for comparisons with the current female scores.

A standard battery of skill tests, similar to the American Association of Health, Physical Education and Recreation AAPHER Basketball Skills Test Manual for Girls (1966), should be devised and adopted by the Canadian Hockey Association for use by both male and female players. It is difficult to assess the reliability of skill tests when baseline scores or even descriptions of previous skill tests are unavailable. Players should have the opportunity to compare their skill level to other hockey players of similar age or even assess their own progress over the course of a season. Unfortunately for the players and the current researcher that was not possible at the time of this study.

Surveys

Three of the 17 questions reported in the basketball surveys by Husak et al. (1984) were similar to those in the hockey surveys. Sixty-two percent of the female hockey players felt they would enjoy playing with the lighter projectile (See Table 4-6) while only 25% of the basketball players felt they would enjoy playing with the lighter ball. When asked if the players preferred the lighter projectile the responses were nearly identical, 48% said yes for the basketball players and 45% said yes for the hockey players

(See Table 4-8). Forty-seven percent of hockey players (See Figure 4-8) and sixty-eight percent of basketball players did not feel it took a long time to adjust to the lighter object. A larger sample size in the basketball study and the fact that the new basketball differed in size and weight may have accounted for the difference in responses to the surveys. Phase 4 of the study by Husak et al. (1984) included the same survey as in Phase 2 of the report. A total of 1417 high school basketball players completed the surveys as well as 124 coaches and 102 referees. For the purposes of this study only the responses of the basketball players were of interest.

The basketball surveys were distributed to the players after the players competed for an entire season with the smaller, lighter basketball. Responses were much different than Phase 2 of the study as the players had an entire year to get accustomed to the lighter, smaller ball. Nintey-three percent of the participants from Phase four of the study by Husak et al. (1984) liked the idea of playing with a lighter projectile compared to only 25% of the basketball players in Phase 2 and 62% of the female hockey players (See Figure 4-8). A greater percentage of the players in Phase 4 (95%) preferred the smaller ball whereas only 48% and 45% of the basketball players in Phase 2 and the hockey players (See Figure 4-8), respectively, preferred the lighter projectile. Twenty-six percent of the hockey players (See Figure 4-8) and 27% of the basketball players from Phase 2 of the Husak et al. study (1984) felt it took a long time to adjust to the lighter projectile, only 12 % of the players from Phase 4 of the study agreed.

The most significant reason for the large differences in the responses of the Phase 2 participants and the hockey players to those of the participants of Phase 4 of the basketball study is the exposure time to the new projectile. Players in Phase 4 had a full season to experience, adapt to, and assess the effects of a smaller, lighter ball on skill performance. In the current study and Phase 2 of the basketball study, players only had several minutes to use the new projectiles before testing was commenced. It is very difficult for players of any level to adapt to a new projectile in that time period. Phase 4 of the study by Husak et al. is an excellent example of the positive effects additional practice time can have on the attitudes of the players within the sport. Short-term testing is useful to evaluate test protocols and initial attitudes that may exist but long-term testing must be incorporated before a final decision is passed to adopt a new projectile into any sport. The decision to adopt a lighter puck into women's hockey should not be made until long-term testing is initiated and completed.

The concern in women's hockey is that much of the game is played on the ice and the majority of shots taken during the course of a game are from in close to the goaltender. The Canadian Hockey Association's Board of Directors feel that in order to maintain or decrease attrition rates of players and maintain or improve attendance, the sport of ice hockey needs to progress. If the players took more shots from further away from the goal that challenged the goaltenders to a greater extent, the game would be even more exciting than it is now. As well, higher shots would increase excitement and make it more difficult for the goaltenders to stop the puck. Additional concerns, voiced by the Canadian Hockey Association's Board of Director's are that the goalies are not challenged enough and that many new players, young or old, experience frustration when performing puck skills. Difficulty in acquiring new skills or improving on old ones often causes players to quit as the sport is no longer enjoyable. If a lighter puck allows players to raise the puck more easily and shoot and pass with a greater velocity, some of these concerns may be addressed. In addition, if players are able to acquire new skills more quickly, attrition rates of female hockey players may improve and more new players may enroll in hockey programs.

Survey results suggest that the lighter pucks do allow players to raise the puck more easily, and shoot and pass the projectile with a greater velocity than the regulation 6.0 oz puck. Although these are positive benefits of a light weight puck, many of the individuals surveyed believe the lighter disc would be detrimental to the image of female hockey and would be labeled a "game for the weaker sex" or "not real hockey". The National Women's team, on the other hand, felt a lighter puck would revolutionize the women's game and possibly make the game more skillful. It is interesting that the top female hockey players in Canada do not feel threatened by a lighter puck and believe it would benefit the game. The NWT players suggested that the main difference between men's and women's hockey is that the male players can shoot and pass with a greater velocity than the female players, mainly because male players are stronger. There was a concern that the light weight pucks are more difficult to handle and bounce and flutter more than a regulation puck. Results of the Passing skill test supported the player's beliefs when the 4.5 oz puck was used as significantly greater times were recorded with the lightest projectile.

Results of the pre and post test surveys suggested that there was a difference in the attitudes towards the use of a light weight puck between the Canadian National Women's team and the Canadian National U22 team. Both teams stated that a lighter puck could be shot and passed with a greater velocity than a regulation puck, as well as raised off the ice more easily. However, the U22 team believed that female hockey would be viewed more negatively if the lighter puck were adopted, players of the NWT believed a lighter puck may actually improve the image of the sport and make the game more skillful.

Although only one of the variables investigated yielded significant results, the data suggests that a lighter puck may address the concerns of the Canadian Hockey Association's Board of Governors regarding the game of women's ice hockey. A few of the concerns of the Board of Governors is that the puck is not raised off the ice as frequently as in a men's game, shots are often taken from in close to the goal and are not challenging enough for the goaltenders. The Canadian Hockey Association is hopeful that the lighter puck would address their concerns and help make female hockey even more exciting than it is now.

The greatest obstacle in adopting the lighter projectile appears to be the image of women's hockey and how it may be tarnished if the lighter puck is accepted into the sport. Players, coaches, officials, parents and fans must keep in mind that female hockey is not to be compared to the sport of male hockey. The two sports are different in that the players from each sport differ in size and strength. Many sports including basketball and track and field events have modified equipment for the female athletes to address the size and strength differences that exist between the genders. "Males are, on average, 10 cm taller and 10 kg heavier than the average female; males are 30 percent stronger in the lower body and up to 50 percent stronger in the upper body than females, males have faster movement time and reaction time; males have only one third to one half of the percent body fat of females; males have wider shoulders and a higher centre of gravity than females" (Alexander, 2001, p. A9). The main goal of the female hockey community should be to make the game of women's hockey as progressive, exciting and as skillful as possible. The differences between the two sports and the athletes that participate in them should be recognized and appreciated.

If the sport of women's hockey does decide to adopt a lighter puck, the statement made by Jill Hutchinson, acting chair of the United States Girls' and Women's Basketball Rules Committee, at the time the smaller, lighter basketball was adopted into women's basketball, should be acknowledged. "The use of the smaller basketball has become a reality. To those of you who support its adoption, we hope it is all you hoped it would be. For those of you who are opposed to the smaller basketball, your voices have been heard. Perhaps your most viable option is to utilize the basketball for one season, critically evaluate the strengths and weaknesses, and prepare your arguments for next spring" (Hutchinson, 1984, p.21).

CHAPTER 6

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY

The purpose of the study was to determine the effects of a light weight puck on the biomechanics of the wrist shot, as well as the puck velocity and accuracy of the wrist shot among female hockey players. A subproblem was to determine if any differences exist in the stickhandling, passing and goaltending skills of female players when using a light weight puck. A further subproblem was to gather attitudinal data and determine if a difference in attitude exists between the two age groups and if the female players would support the adoption of a light weight puck. This was done to determine if a light weight puck would enhance the women's game and allow for more shots, shots and passes with a greater velocity, higher shots, shots taken further from the goal and the opportunity for players to challenge the goalies to a greater degree. It was hypothesized that the biomechanics of the wrist shot and the players performance on the hockey skill tests would not differ between the four puck weights (4.5 oz, 5.0 oz, 5.5 oz and 6.0). Additionally, attitudinal data would not differ between age groups and the female players would not support the adoption of a lighter puck.

Data were collected on 12 members of the Canadian National Women's team (NWT) for the wrist shot filming and 25 members of the Canadian National U22 Women's team (U22) for the hockey skill tests. Participants for the NWT and the U22 team were also required to complete pre and post test surveys before and after testing. Players performed their respective tests with four different pucks; the regulation 6.0 oz puck and the three newly designed light weight pucks (4.5 oz, 5.0 oz and 5.5 oz).

Significant differences in puck velocity between wrist shot trials with the four pucks weights was not evident. A negative correlation was demonstrated for puck weight and velocity but the correlation was not significant. Players did demonstrate that the lighter pucks could be shot with a greater velocity than the regulation puck, although the results were not significant. The mean velocity for the 4.5 oz puck was 20.54 m/s or 46.22 mph, the 5.0 oz puck had a mean velocity of 19.88 m/s or 44.73 mph, a mean velocity of 19.68 m/s or 44.28 mph was demonstrated for the 5.5 oz puck and the regulation, 6 oz puck, had the least mean velocity at 19.53 m/s or 43.93 mph. Wrist shots with the 4.5 oz puck were 2.25 mph faster than those with the 6.0 oz puck.

The biomechanics of the wrist shot did not significantly differ when the players executed a wrist shot with the lighter pucks. The angular displacement and velocity of the stick blade did not differ between puck weights, however, results suggested that peak angular velocity of the stick blade occurred within 0.07 of puck release or critical instant.

Significant differences in hip angular displacement and velocity did not occur and no specific patterns were evident in the data. This may have been due to the fact that there was difficulty in accurately digitizing the hip joint. Results suggested that the players achieved peak hip velocity within 0.05 s before puck release.

Shoulder angular displacement and velocity did not demonstrate any significant changes when the players performed the wrist shot with the lighter pucks. Players did display similar mean shoulder angular displacement values ranging from 376.07deg/s^2 with the 5.0 oz puck to 419.48deg/s^2 with the 5.5 oz puck. Mean shoulder angular velocities for the 4.5 oz puck and 5.0 oz puck were also within this range. The results of the shoulder girdle analysis did suggest that the majority of players produced peak angular velocity of the shoulder girdle within 0.06 seconds of puck release.

Results for the resultant linear displacement of the center of gravity of the players did not reveal any significant differences when the players executed the wrist shot with the four puck weights. Results suggested that resultant linear displacement was greatest with the lightest, 4.5 oz puck (0.257 m) and the least with the heaviest, 6.0 oz puck (0.13 m).

Skill test results significantly differed between the four puck weights in the Passing skill test but not in the Accuracy Shoot, Puckhandling, Rapid Fire or Breakaway skill test. Results of the Passing skill test demonstrated significantly greater (slower) times for the 4.5 oz puck (8.4 s) than the 5.0 oz (7.22 s), the 5.5 oz (7.29 s) and the 6.0 oz (7.5 s) pucks.

Rapid Fire and Breakaway skill tests suggested that the goaltenders achieved a higher save percentage when the players were using the regulation 6.0 oz puck (67% and 89%, respectively). Players had the lowest shooting percentage in the Rapid Fire skill test (13%) and the Breakaway skill test (12%) when using the regulation puck.

Results of the pre test survey suggested that a difference in attitude does exist between the NWT and the U22 team in relation to the adoption of a light weight puck into the game of women's hockey. Ninety-two percent of the NWT believed that the biggest difference between men's and women's hockey is harder shots while only 44% of the U22 team agreed. Over 84% of the participants in both groups stated that women cannot shoot the puck with the same velocity as male players, 100% and 88% of the NWT and U22 team, respectively, suggested strength is the main reason for this difference. Forty-two percent of the NWT felt it was a "good idea" to adopt a lighter puck into women's hockey while 4% of the U22 team agreed. The majority of the U22 players believe that women's hockey would be viewed as a "game for the weaker sex" or "not real hockey" whereas the majority of the NWT stated a lighter puck would "revolutionize the game" and make it more well played.

Post test survey results suggested that 58% and 41% of the NWT and U22 team members, respectively, prefer the lighter pucks to the regulation pucks. About half of the players from each age group did not have trouble adjusting to the lighter pucks after one ice session. At least 89% of the participants in each group felt the lighter pucks could be raised off the ice more easily than the regulation pucks. Ninety-two percent of the NWT stated that a lighter puck would enhance the development of shooting and passing skills in women's hockey, only 42 % of the U22 players agreed. The most common problem with the lighter puck is that the players felt it would be too light and difficult to handle. In addition, 74% of the U22 team still believed that women's hockey would be viewed as "a game for the weaker sex" whereas only 25% of the NWT agreed.

Results of the data from the wrist shot filming, hockey skill tests and questionnaire surveys reveal that, for the most part, there is no significant reason to adopt a light weight puck in women's hockey. However, the major concern with women's hockey is that the game is played "on the ice" and "in too close to the goalie". The results do suggest that lighter pucks can be shot with a greater velocity and raised off the ice more easily. Additionally, goalies had a lower save percentage with the lighter pucks than the regulation puck. Faster and higher shots, and more goals would definitely be an asset to women's hockey, according to the Canadian Hockey Association. The most negative aspect of the adopting a lighter puck appears to be the way that the sport will be viewed if a lighter puck is accepted.

Conclusions

Based on the results of the present study, the following conclusions are justified:

1. Puck velocity was not increased when the players executed the wrist shot with lighter pucks.
2. Angular displacement and velocity of the stick blade did not differ when lighter pucks were used.
3. Hip angular displacement and velocity did not significantly differ with the use of lighter pucks.
4. Shoulder angular displacement and velocity did not significantly differ with the use of lighter pucks.
5. Linear displacement of the center of gravity of the player did not significantly differ with the use of a lighter puck.
6. Players' performance in the Accuracy Shoot skill test did not change when the test was performed with the lighter pucks.
7. A change in performance was not evident when the Puckhandling skill test was performed with the lighter pucks.
8. No evidence of a significant change in performance occurred when the participants performed the Rapid Fire skill test.
9. Results of the Passing skill test were significantly slower when the players used the 4.5 oz puck as compared to the other three puck weights to perform the test.

10. Results of the Breakaway skill test did not differ when the test was performed with pucks of different weights.
11. There is a difference in the attitude of players towards the use of a light weight puck in women's hockey between age groups.
12. There is not an overwhelming majority of players from both teams that support the adoption of a lighter puck into the game of women's hockey.

Recommendations

The following recommendations are made for future studies on women's hockey:

1. Players should wear tight fitting attire of contrasting colors on their trunk and limbs when filming is performed. Additionally, players should be required to remove their hockey gloves so that more accurate digitization can be performed on the film data.
2. More detailed studies should be performed on the biomechanics of the wrist shot and the contribution of forearm pronation to the velocity of the shot. Comparisons of the shooting technique of male and female players is also important to determine if biomechanical shooting differences exist between the sexes.
3. A standardized skill testing manual should be developed to provide players, coaches and researchers the opportunity to more accurately assess skill levels and progress.
4. Longitudinal studies should be performed on the effects of a light weight puck in women's hockey to determine if attitudes, skill performances and skill development are affected when players have more time to practice with the lighter projectile.
5. Strength data and wrist shot velocities should be compared to investigate the effects of strength on puck velocity and which muscles demonstrate the greatest contribution to shot velocity.

6. Game statistics in women's hockey leagues should be analyzed over the course of a year to determine if a light weight puck results in more shots, shots from a greater distance, higher shots and more goals.

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APPENDIX A

Personal Consent Form

CANADA

CANADA

Participant Consent Form

You have volunteered to participate in a study entitled "The effect of the use of light weight pucks in women's ice hockey ". This research study is funded by the Canadian Hockey Association and is being completed by the Investigator, Jeff Leiter, a graduate student in the Faculty of Physical Education and Recreation Studies at the University of Manitoba.

The only requirements are that you are a healthy female, in accordance with your pre-season medical, between the age of 18 and 30, and participate on the Canadian National Women's Team in the sport of ice hockey. In addition, you must not have experienced upper body injuries in the past three years that have kept you out of competition for more than a week.

The purpose of this study is to investigate the effects of the use of light weight hockey pucks on the game of ice hockey. More specifically, the implications of a lighter puck on the technical and tactical development of players, the speed of the game and goaltending will be examined by analysis of videotape.

Players will be filmed from the front and side view executing a wrist shot with the light weight and regulation pucks. Five attempts will be taken with each of the 3 light weight pucks and the regulation puck for the wrist shot. Players will be randomly selected to the order in which the pucks will be shot. Players will complete a total of 20 consecutive shots within the testing period.

Your name, age and results will be recorded by the Investigators and all information and video footage will remain confidential.

If for any reason you feel it necessary to speak with the Investigator, Jeff Leiter you can do so by calling (204) 474-6875, or the Advisor, Dr. Marion Alexander at (204) 474-8642.

I, ______________________________, have read the above information and understand the testing procedure, that there are no additional risks than those already assumed by playing hockey, and I agree to participate at my own risk. I acknowledge that the skills involved are within my capability and I can successfully perform these skills on a regular basis. I also understand that I have the right to withdraw from this study at any time. In case of injury, I relieve the University of Manitoba and the Investigators of any liability that may result from my participation in this study.

______________________________ ______________

Signature of Investigator **Date**

______________________________ ______________

Signature of Participant **Date**

______________________________ ______________

Signature of Witness **Date**

APPENDIX B

Pilot Study

PILOT STUDY

METHODS

Wrist Shot Filming

Subjects

A pilot study was performed on June 12, 2000, at the University of Manitoba, in the Max Bell Arena. The goals of the pilot study were to determine if the camera set-up would provide accurate data for video analysis, to investigate the time required to perform the skill tests and to assess the effectiveness of surveys regarding the attitudes of female hockey players towards the use of a light weight puck in their sport. Seven subjects were recruited for the pilot study, five of whom played at the University of Manitoba and competed in the Canadian Interuniversity Athletic Union (CIAU). The other two subjects have played hockey for at least 3 years at a recreational level. The characteristics of the subjects are outlined in Table B-1.

Table B-1 Subject characteristics

Table 1 Subject Data

	Sex (M/F)	Group (1/2)	Age (years)	Height (cm)	Weight (kg)	Shoots (L/R)
Subject 1	F	2	21	167.5	79.5	L
Subject 2	M	1	25	190	99.1	L
Subject 3	M	2	24	182.5	85	L
Subject 4	F	1	21	165	80	L
Subject 5	M	1	21	192.5	90.9	R
Subject 6	F	2	20	167.5	72.7	R
Subject 7	F	1	27	165	68.2	R
mean			22.7	175.7	82.2	
std. dev.			2.63	12.2	10.5	

Pre-activity warm-up

The warm-up was performed to reduce the risk of injury during testing and to familiarize the subjects with the four pucks of different weights. Subjects were required to perform 10 wrist shots against the boards with each of the four different puck weights, in order from lightest to heaviest puck or the heaviest to the lightest puck depending on which group the subject was placed in. Prior to the standardized warm-up subjects skated around the ice stickhandling with the standard puck and shooting on a goalie located at the opposite end of the ice surface to where the testing was to take place. Although subjects did stretch, it was not standardized nor recorded.

Filming technique for the wrist shot

Two cameras were used for video analysis, each filming at 30 Hz or 30 frames per second and placed perpendicular to one another. The sagittal view of the subject was filmed using a PANASONIC PV-S770A-K® model while the frontal view was recorded with the PANANSONIC PV-4600K® model. Camera 1 was placed in a protective Plexiglas box lined with foam to absorb the shock of an incoming puck. A cement brick was placed between the bottom of the box and the goal net at the rear of the box to angle the camera towards the shooter. This allowed for full view of the body and stick of the player. The protective box was secured to the net with 4 rubber bungee cords. Two of the cords were hooked together and placed behind the lip of the opening at the top of the box and attached to the front of the mesh of the top of the net. These cords prevented posterior translation of the box and eliminated the possibility of it sliding off the net towards the boards. The other two cords were hooked together and placed on the anterior and superior aspect of the box and strapped tightly against the cross bar of the goal net.

The box was placed in the center of the top of the net and was located 6 metres from the placement of the puck. The frontal view camera was secured to a tripod about 4 metres from the location of the puck and perpendicular to the sagittal view camera. Each camera was set at a shutter speed of 1/500 as the lighting in Max Bell Centre did not allow for a higher shutter speed.

Following camera set-up the cameras were calibrated using a calibration tree from Peak Technologies. The calibration tree was placed directly over the spot marked on the ice where the puck was placed to ensure that it encompassed the area that was to be occupied by the shooter.

Experimental protocol for wrist shot filming

The pucks were positioned 6 metres from the centre of the goal net between the two face-off circles. A frisbee, 25 cm in diameter was hung, approximately, in the vertical and horizontal centre of the goal. Left handed players shot first to accommodate for the camera set-up, followed by the right handed shooters after the frontal view camera was placed on the opposite side of the shooting area. The calibration tree was placed in the shooting area before the left handed shooters began their trials and again before the right handed shooters began testing to calibrate the frontal view camera. Participants were instructed to take five wrist shots with each puck and aim the puck towards the target. If the wrist shot contacted the target it was recorded as a hit and if it missed the target it was recorded as a miss. The players were instructed to take a slight pause between shots and perform each shot as they would in a game or practice situation. The subjects performed the shots in the same order as they did in warm-up with group 1 shooting the 4.5 oz puck first and progressing to the regulation puck last (4.5, 5.0, 5.5, and then 6.0 oz). Group 2 performed the tests in the opposite order. After each player took five shots with each of the 4 puck weights for a total of 20 shots, the test was complete and the player was asked to leave the ice.

Video Analysis

Video film analysis was conducted with a video motion analysis system from Peak Performance Technologies (1994). This video analysis system consists of Peak 5 software (version 5.2), a Sanyo GVR-SP55 video cassette recorder (Sanyo, Compton, California), a Sony Trinitron PVM 1341 color video monitor (Sony Corporation, Ichinomyia, Japan) an ALR IBM compatible personal computer (ALR Technologies, California), a NEC MultiSync 2A computer monitor (NEC Corporation, Tokyo, Japan), a Hewlett-Packard LaserJet series II printer and a Hewlett-Packard LaserJet series II printer and a Hewlett-Packard 7475A plotter printer (Hewkett-Packard Company, San Diego, California).

A spatial model, or computer representation of a hockey player was created to define 14 segment model of the human body and a 1 segment model of a hockey stick. The spatial model consisted of 25 points including points for the butt, heel and blade of the hockey stick as well as the center of the puck. For each frame of video film, 25 points on the body and stick were digitized to mark the landmarks of the shooter that define the computerized spatial model. The centre of mass of the spatial model was also calculated by the computer soft ware and labeled as point 26. Digitization began approximately one frame before initial movement towards the net and was completed near the end of the player's follow through. Although only calculations for the stick and puck were calculated in 3D, a 25 point model was set-up to ensure that digitized points could be located throughout the skill by at least one of the cameras. The camera configuration worked very well and all points could be seen by at least one camera at all times during the skill. The center of mass, (point 26) was also calculated as the displacement of the center of gravity is a variable that may be included in the future

One of the five shots for each of the pucks was selected for digitization and analysis based on accuracy (how close the puck was to the target) and the velocity of the shot. The velocity of the shot was estimated using frame by frame analysis on a VCR. This process consisted of placing an overhead transparency on the TV monitor and marking the puck on the transparency in two consecutive frames. The distance traveled by the puck on the screen was multiplied by the conversion factor to determine the actual linear displacement of the puck. The linear displacement was then divided by the time between video frames to obtain the linear velocity of the puck.

The fastest shot of each puck weight, as calculated by the manual method, was then calculated using the Peak Performance Video Analysis System. In addition, the angular displacement and angular velocity of the stick blade was calculated to estimate the amount of pronation of the forearm of the bottom hand on the hockey stick, during the wrist shot. The angle of the stick blade was calculated by connecting the toe of the blade to the heel of the stick and using the heel of the stick as the origin of the x axis. The minimum and maximum angles of the stick blade were calculated to determine the angular displacement of the blade of the stick.

Statistical analysis

A repeated measure analysis of variance (ANOVA) was used to analyze the results of the wrist shot variables. The results for puck velocity, angular displacement and angular velocity of the stick blade were compared between puck A, B, C, and D for each individual. The subjects were placed in 2 groups during testing but due to the low number of subjects in the study, group comparisons were not calculated as the power of the test would be too low.

Hockey Skill Tests

Subjects

The hockey skill test was performed on Saturday, July 22nd, 2000 at the University of Manitoba in the Max Bell Centre. Subjects for the hockey skill tests were four female hockey players from the University of Manitoba Women's Hockey team and one player from the Winnipeg High School Hockey League. Four of the participants were regular players while the other participant was a goalie. The characteristics for the subjects are outlined in Table B-2. Players were required to fill out a personal consent form prior to the testing session as well as a pre-test survey. Players were included on the basis that they were a healthy female in accordance with their pre-season medical and had not experienced an injury in the past three years that kept them out of competition for more than one week.

Table B-2 Subject characteristics

Subject Data						
	Sex (M/F)	Group (1/2)	Age (years)	Height (cm)	Weight (kg)	Shoots (L/R)
Subject 1	F	2	22	162.5	61.4	L
Subject 2	F	2	18	165	54.5	L
Subject 3	F	1	21	170	72.7	L
Subject 4	F	1	21	167.5	79.5	L
Subject 5	F	goalie	20	167.5	72.7	L
mean			20.4	166.5	68.2	
std. dev.			1.5	2.9	10	

Pre-activity warm-up

Warm-up was implemented to reduce the risk of injury during the testing period and to familiarize the subjects with the four pucks of different weight. The warm-up was 10 minutes in duration and subjects had 2 ½ minutes with each of the four pucks. During the 2 ½ minutes with each of the pucks the subjects could shoot, pass, or stickhandle the puck, the main objective was to let the subjects get accustomed to the lighter pucks. Players were placed into 2 groups, group 1 performed the warm-up with the lightest puck first and progressed to the regulation puck (4.5, 5.0, 5.5, and 6.o oz) while group 2 performed the warm-up in the opposite order. Players did stretch, however it was not standardized nor recorded.

Experimental protocol

Subjects were randomly selected into two groups although the number of participants in each group was so small, data was not compared between group. Both groups were required to perform the skill tests in the same order as they did in the warm-up.

The first skill test that the subjects performed was the Accuracy Shoot. A circle was spray painted on the ice 6 metres from the centre of the goal. Four targets, 38 cm in diameter were placed in the corners of the net, suspended by nylon straps to the cross bar and secured to a nylon strap that ran from one post to the other near the bottom of the net. The straps prevented excessive movement of the targets after the targets were contacted by a puck, allowing the player to continue without delay. Players were given eight pucks and the goal was to contact each of the four targets in as few shots as possible. If the four targets were hit with less than eight shots the player was not required to shoot the remaining pucks. Subsequently, if the player did not hit all four targets with the eight pucks, the test is stopped and the score of the player is recorded as the number of hits/the number of shots. Group 1 and 2 performed the tests in the same order as they did in warm-up. Each subject completed one trial before the next player shot, the players continued the test until four trials, one with each of the four pucks were completed.

The second skill test the players performed was the Puckhandling skill test. Six cones were placed in a straight line 6 metres apart. Players began the test in the start/finish gate located 6 metres from the first cone. Forward movement of the player started the stopwatch and the player weaved through the cones. When the player arrived at the last cone, she was required to round it and continue through the cones to the start/finish gate. The clock was stopped when the first body part, not the stick, of the individual entered the gate. If the player lost the puck during the course of the test, she was required to retrieve the puck and enter the course where the puck was lost, the time continued to run until the player completed the course. Group 1 and 2 performed the tests in the same order as the warm-up. Each player performed the test with one puck, followed by the next subject in order to give the players time to rest between trials and eliminate or decrease the effects of fatigue as a variable for the time to perform the test.

The third test performed was the Rapid Fire skill test. Five pucks were placed at designated locations (indicated by spray paint on the ice) 6-7 metres from the goal line. Players were required to shoot the pucks within 10 seconds or the test would have to be repeated, this time limit was not a factor as most of the players shot the 5 pucks within 7-8 seconds. The goalie was required to have her skates in the goal crease at all times during the test. If the goaltender left the crease, the test was stopped and performed again. The time required by the players to shoot all 5 pucks was not recorded, shots were scored as either a goal (g), a save (s), or a miss (m). After player 1 completed the first trial, the other players shoot in order until player 1 is up again. A shot that misses the net or contacts the goal post was considered a miss and not a save by the goaltender.

The Breakaway skill test was the fourth skill test in the battery of skill tests. Three pucks were placed on the blue line and the player made three consecutive attempts to score on the goalie. The goalie was required to stand on the goal line until the player contacted the first puck and had to return to the goal line after each shot and remain on the goal line until the next puck was touched. Players were not allowed to score on rebounds and had to move continuously in the forward direction until the shot was taken. The attempt was recorded as either a goal or a save by the goaltender. Contrary to the Accuracy Shoot, if a player missed the net, it was considered a save by the goalie because many times a player will miss the net as a result of the goalie's actions. For example, the goalie may slide to one side of the goal and force the player to shoot from a bad angle, this is characteristic of a highly skilled goalie and the goaltender should be awarded a save for this skilled movement. In the Rapid Fire test the goalie must stay in the crease and the player must shoot from set locations. When the player misses the net it is not a result of the goaltender's actions, rather an inaccurate shot by the player, and the goalie should not be credited with a save. Each player performed one trial with the designated weight and then rested until the other players had completed their first trial.

Passing and Receiving was the fifth test performed. The player was positioned 6 metres from the instructor and was required to remain within the 2 diameter passing circle. This circle was marked on the ice with paint and if the player left the circle during the test, the test was stopped and the stopwatch was reset. The player was required to give and receive ten passes as quickly as possible. The stopwatch began when the player released the first pass and was stopped when the player received the tenth pass. If the puck was mishandled or a poor pass was made by the instructor (misses the player's stick) the test was stopped, the clock was reset, and the player began again. If the puck was mishandled by the player or the player missed the instructor's stick, the puck was retrieved and the time continued to run until the player completed the test. The time required to complete ten passes was recorded at the end of the trial. Contrary to previous tests each subject performed two trials with each puck before the next person performed the skill. The Passing and Receiving test also took longer than anticipated and the protocol will be changed for the final testing. Each player will only make five passes with each of the puck weights, consecutively. After each player has performed one trial with each puck, they will be required to perform a second trial. A second trial is required for this test as the results of the tests are also dependent on the skill of the Instructor and one poor trial would produce inaccurate results if the player did not receive another attempt.

Statistical analysis

A repeated measure analysis of variance (ANOVA) was used to analyze the results of the five skill tests. The results for each of the skill tests were compared between puck A, B, C, and D for each individual. The subjects were placed in 2 groups during testing but due to the low N in the study, group comparisons were not calculated.

SURVEYS

The participants were also required to complete a survey at the beginning and end of each ice session. The surveys were designed to assess the attitudes of the players towards the use of a light weight puck in women's hockey before and after the subjects had experimented with the new projectiles. Subjects for the pre-test survey included participants from the Western Shield Hockey Championships in Winnipeg, Manitoba from April 7-9, 2000. A total of 76 participants completed the pre-test survey.

The post test survey included the subjects from the hockey skill test and the players completed the survey after the battery of skill tests were completed. Although the number of subjects (N=5) was very low it was interesting to assess the change in attitudes of the players after they had experimented with the lighter puck.

RESULTS FOR THE WRIST SHOT

Since the number of subjects was very low in the study, it was not possible to make comparisons between groups. The first variable calculated was puck velocity and the fastest recorded velocity was 28 m/s or 63 mph, consistent with the wrist shot velocity of a highly skilled hockey player (Table B-3). There was a large variability in the data as some subjects demonstrated a decrease in peak puck velocity when using a heavier puck while others recorded a higher velocity with a heavier puck. It should be noted that the most skilled shooters in the group were the most consistent shooters in terms of velocity and were the subjects that demonstrated a very slight increase in velocity with decreased puck weight .

Table B-3 Puck Velocity

Puck Velocities

	Sex	Group	puck release (frame #)	puck velocity m/s	B-A, C-B, D-C m/s	C-A m/s	D-A m/s
Subject 1, Puck A	f	2	28	20.1			
1B			26	18.48	-1.62		
1C			30	20.19	1.71	0.09	
1D			26	19.96	-0.23		-0.1
Subject 2, Puck A	m	1	32	26.51			
2B			20	25.56	-0.95		
2C			20	25.58	0.02	-0.93	
2D			23	24.86	-0.72		-1.7
Subject 3, Puck A	m	2	21	28			
3B			16	26.28	-1.72		
3C			17	27.5	1.22	-0.5	
3D			24	26.31	-1.19		-1.7
Subject 5, Puck A	m	1	11	20.99			
5B			16	22.32	1.33		
5C			16	23.37	1.05	2.38	
5D			24	26.49	3.12		5.5
Subject 6, Puck A	f	2	10	15.73			
6B			12	15.84	0.11		
6C			10	16.19	0.35	0.46	
6D			15	16.65	0.46		0.92
subject 7, Puck A	f	1	11	16.86			
7B			8	16.82	-0.04		
7C			7	16.61	-0.21	-0.25	
7D			9	17.61	1		0.75
mean				21.45	-0.844	-0.23	-0.4
standard deviation				4.36	0.86	0.53	1.26

The results of stick blade angular displacements and velocities, shown in Table B-4, were inconsistent and demonstrated a large variability for each player. However, the amount of stick blade displacement ranged from 22.5 to 113.5 degrees which is consistent with a highly skilled shooter depending on the height of the shot taken. For example, if a player attempts to raise the puck, the blade of the stick must be rotated posteriorly to direct the puck to the upper portion of the net. During the follow through the blade is rotated anteriorly in a rapid movement, therefore, angular displacement of the stick would be greater than a low shot. It was interesting to note that the maximum angular velocity of the stick blade occurred within one to two frames after puck release suggesting that the subjects are achieving peak angular velocity of the stick blade at the correct instant during the wrist shot. As the puck is released and the weight of the puck is removed from the stick blade, the angular velocity of the stick reaches its peak velocity indicating that the blade of the stick was rotating at a very high velocity just prior to release. (Table B-4).

RESULTS OF THE HOCKEY SKILL TESTS

With only five players competing in the skill tests it was not possible to obtain significant results. In addition, the players only performed each skill test once instead of twice as time became a limiting factor. The skill tests did provide the investigator and the players an opportunity to evaluate how a light weight puck affected certain skills. The skill test also provided useful insight into the characteristics of the pucks (amount of bounce, amount of flutter, whether the puck was dense enough to sustain high velocity impacts without deforming) which must be considered when selecting an appropriate weight for each age level. Since the number of subjects was so small, results of the skill tests were only compared within the individual not between individuals as the power of the test would be too low.

Although the data for the characteristics of the pucks was not recorded it was evident that the 4.5 oz puck did flutter and bounce more during the passing and shooting skill tests. The 4.5 oz puck also deformed when it contacted the goal post at a high velocity. These are two characteristics that must be taken into account when selecting a new puck weight.

Table B-4 Stick blade displacements and velocities

Stick Blade Displacements and Velocities

	Sex	Group	puck release (frame #)	max. angle (deg)	max. angle (frame #)	min. ang. (deg)	min. ang. (frame #)	ang. disp. (deg.)	ang. vel. (-) deg/s (frame #)
Subject 1, Puck A	f	2	28	171.6	27	88.7	33	82.9	1325.31 (30)
1B			26	172.5	24	116.7	32	55.8	758.51 (27)
1C			30	173.7	28	102.8	37	70.9	1009.24 (31)
1D			26	134	3	111.5	20	22.5	1457.9 (27)
								0	
Subject 2, Puck A	m	1	32	170.3	31	61.4	37	108.9	1725.8 (33)
2B			20	170.1	19	73.8	24	96.3	1658.1 (22)
2C			20	168.3	18	76.5	25	91.8	1369.1 (21)
2D			23	168.8	22	60.95	30	107.85	1563.93 (25)
								0	
Subject 3, Puck A	m	2	21	172.9	20	75.2	26	97.7	1328.75 (23)
3B			16	176.6	14	64.8	20	111.8	2037.49 (18)
3C			17	174.1	15	60.6	20	113.5	1900.76 (19)
3D			24	172.9	22	60.6	29	112.3	1563.25 (26)
								0	
Subject 6, Puck A	f	2	10	60	7	96.4	26	-36.4	-931.00 (17)
6B			12	77.2	8	22.1	17	55.1	704.72 (12)
6C			10	80.2	7	23.6	14	56.6	831.02 (9)
6D			15	83.4	12	22.3	20	61.1	905.54 (15)
								0	
subject 7, Puck A	f	1	11	89.3	5	25.2	17	64.1	859.34 (9)
7B			8	88.5	3	24.6	14	63.9	808.3 (7)
7C			7	92	3	17.4	14	74.6	1054.4 (14)
7D			9	98.2	5	23.1	15	75.1	1108.6 (8)
mean									
standard deviation									

The first skill test, the Accuracy Shoot, suggested that the players were less accurate with the lighter pucks (Table B-5), in particular, the 4.5 oz puck (44%). The players were most accurate with the 5.5 oz (54%), slightly higher than the regulation puck (53%). It was interesting to note that the players hit each of the 4 targets in all but 4 trials, with the majority of the players demonstrating s shooting percentage of 50% for most of the trials.

Table B-5 Accuracy Shoot

Accuracy Shoot
hits/shots

	4.5 oz	Shooting %	5.0 oz	Shooting %	5.5 oz	Shooting %	6.0 oz	Shooting %
Player 1	4/8	50	4/8	50	3/8	38	4/8	50
2	4/8	50	4/5	80	4/4	100	4/6	67
3	4/8	50	4/8	50	4/6	67	4/8	50
4	2/8	25	3/8	38	3/8	38	4/8	50
Total	14/32	44	15/29	52	14/26	54	16/30	53

The second test performed was the Puckhandling test, it was difficult to observe a pattern in this data as each subject only performed one trial with each of the light weight pucks. The results of the group did suggest that the time to stickhandle through the course was slightly lower with the 6.0 oz puck (14.66) than with the other three puck weights (**Table B-5**).

Table B-5

Puckhandling
(seconds)

	4.5 oz	5.0 oz	5.5 oz	6.0 oz
Player 1	15.13	14.75	14.85	14.72
2	14.65	18.72	15.19	14.41
3	14.94	14.91	14.91	14.97
4	14.47	14.15	14.34	14.53
mean	14.80	15.63	14.82	14.66
std. dev.	0.29	1.54	0.24	0.19

As stated earlier, it is difficult to suggest a consistent pattern within this data but is interesting to note that the trials were very similar within each subject and between subjects. The fact that some of the times decreased from the trial with the first puck weight to the trial with the last puck weight for each group suggests that the rest interval between trials was significant enough for recovery of the energy systems required for that test.

Following the Puckhandling drill the players moved on to the Rapid Fire test. The results suggest that more goals were scored with the 4.5 oz puck with the other three weights (**Table B-6**).

Table B-6

Rapid Fire
(goal =g, save =s, miss=m)

	Puck A	Puck B	Puck C	Puck D
Player 1	s,m,s,s,s	s,g,s,s,s	s,g,s,g,s	s,s,s,g,s
2	g,g,g,g,m	s,g,m,s,g	g,s,s,s,s	m,s,s,s,m
3	g,g,s,s,s	s,s,s,s,s	m,s,m,s,m	s,s,s,s,s
4	m,s,s,s,s	m,s,s,m,m	m,m,m,m,s	g,s,s,s,s
Total saves	11	13	10	16
Total goals	6	3	3	2
Total misses	3	4	7	2
	20	20	20	20

In regards to the goalie, the goalie made 16 saves with the regulation puck and only 11 with the 4.5 oz puck. The players missed the net the least often with the regulation puck (2) and the most often with the 5.0 oz puck. The data suggests that players may be slightly more accurate with the regulation puck in terms of hitting the net but are more prolific at scoring with the 4.5 oz puck. In addition, it is suggested that the goalie made more saves with the regulation puck, which may indicate the players cannot shoot this puck with the same velocity as the 4.5 oz puck. Therefore, the goalie is able to move quickly enough to stop the puck.

The players proceeded to the Breakaway skill test after the Rapid fire station. The results of this test suggest that the female hockey players were able to score more goals with the 4.5 oz puck **(Table B-7).**

Table B-7

Breakaway
(goal =g, save or miss =s)

	4.5 oz	5.0 oz	5.5 oz	6.0 oz
Player 1	g,g,g	s,g,s	s,s,s	g,s,g
2	s,g,s	s,s,s	s,s,s	s,s,s
3	s,s,s	s,s,s	g,s,s	s,s,s
4	g,g,s	g,s,s	g,s,s	g,s,s
Total goals	6	2	2	3
Total saves	6	10	10	9

In fact, the players scored 50% more goals with the 4.5 oz puck than they did with any other puck. Conversely, the goalie made only 6 of 12 saves with the 4.5 oz puck suggesting that this puck is more difficult to stop than the other three pucks. These results support the results of the Rapid Fire test in that the 4.5 oz puck was the easiest puck for the players to score with and the most difficult for the goalies to stop.

The data from the Passing and Receiving skill test was very unreliable as the time of the player was dependent on the consistency of the Instructor. During the course of the testing, the Instructor became fatigued and it was quite evident that the time of the players decreased because of this. The passes also become more inaccurate and it was very difficult to obtain meaningful results. However, it did give the players a good feel for the puck and was the first indication that the 4.5 oz puck bounced too much. For this reason, it may not be valuable for quantitative data but could provide a very useful qualitative assessment of how the players feel about the pucks.

RESULTS OF THE SURVEYS

The pre-test survey suggested that the majority of the females believe that they do not shoot and pass with the same velocity as their male counterparts. Forty-seven percent of the females interviewed feel that the greater strength of the male players is the main reason for this difference. The female players also felt that males can raise the puck with a greater velocity than females due to the difference in strength between males and females. However, despite this difference only 9% of respondents believe it is a good idea to adopt a light weight projectile where as 57% of the women tested believe it is a bad idea, 26% feel it is worth a try. Surprisingly enough, 70% would be willing to experiment with the lighter puck in practice and 64% would try it in a game.

The biggest issue appears to be the image of women's hockey and how it would be perceived if the lighter puck was adopted. The positive result of the survey is that 70% of the females are willing to practice and experiment with the lighter puck.

The results from the post-test survey are very valuable as the attitudes of the players after experimenting with the lighter projectile are revealed. Each of the 5 subjects stated that they did not prefer to use the light weight pucks after trying the new objects, 4 out of 5 players made the same statement before stepping on the ice. Eighty percent of the players indicated it was difficult to get used to the new pucks and that they did not want to experiment with the pucks in a game. The players preferred the 5.5 oz puck if they had to recommend a light weight puck for women's hockey.

The results of this survey indicate that the women's attitudes have not changed after the light weight pucks were experienced. In fact, there are indications that the attitudes are slightly more negative towards the use of a light weight puck in women's hockey. The goalie did indicate that the 4.5 oz puck was more difficult to stop as the players could raise the puck more quickly.

DISCUSSION

The results of this pilot study suggest that differences in skill performance with a light weight puck are minimal. There is a large variability in the data within and between subjects. However, the study indicates that the more skilled players are more consistent in their skill performance and demonstrate a greater difference in skill performance between puck weights.

The camera set-up for the wrist shot worked very well as it provided accurate data for video analysis. The sagittal view camera was protected from the impact of the puck which was a major concern during filming.

The hockey skill test protocol will have to be modified as the time to complete the tests was greater than anticipated. Due to the cost of ice rental, the skill test will have to be modified to accommodate the time restrictions placed on the investigator. More subjects are needed for the skill tests as the tests suggested certain trends in the data but no significant differences were evident. Of course, the effect of the light weight pucks on a goalie's performance is important to this study and will influence the recommendations of this report.

The surveys provided very useful information on the attitudes of female hockey players towards the use of a light weight puck before and after the puck had been experimented with. Data suggests that a major concern of most female hockey players is how the game will be perceived if a lighter puck is adopted.

APPENDIX C

Personal Consent Form for Skill Tests

Participant Consent Form

You have volunteered to participate in a study entitled "The effect of the use of light weight pucks in women's ice hockey ". This research study is funded by the Canadian Hockey Association and is being completed by the Investigator, Jeff Leiter, a graduate student in the Faculty of Physical Education and Recreation Studies at the University of Manitoba.

The only requirements are that you are a healthy female, in accordance to your pre-season medical, under the age of 22, and are participating at the Canadian National Under 22 Women's camp on August 15, 2000. In addition, you must not have experienced any injuries in the past three years that have kept you out of competition for more than a week.

The purpose of this study is to investigate the effects of the use of light weight hockey pucks on the game of ice hockey. More specifically, the implications of a lighter puck on the technical and tactical development of players, the speed of the game and goaltending will be examined by a battery of skill tests.

Players will perform a battery of 5 hockey skill tests that include puckhandling, breakaway, passing/receiving, rapid fire and accuracy shooting. Players will rotate through the skill tests, performing each test with the different pucks in the order determined before testing. During each set of the tests, the player will execute one repetition of the test with 4 pucks of different weights (4.5, 5.0, 5.5 and 6.0 oz). Participants will be outfitted in the same equipment worn in a game or practice situation.

You will also be required to fill out a survey before and after the on-ice session.

Your name, age and results will be recorded by the Investigators and all information and skill test results will remain confidential.

If for any reason you feel it necessary to speak with the Investigator, Jeff Leiter you can do so by calling (204) 474-6875, or the Advisor, Dr. Marion Alexander at (204) 474-8642.

I, ________________________________, have read the above information and understand the testing procedure, that there are no additional risks than those already assumed by playing hockey, and I agree to participate at my own risk. I acknowledge that the skills involved are within my capability and I can successfully perform these skills on a regular basis. I also understand that I have the right to withdraw from this study at any time. In case of injury, I relieve the University of Manitoba and the Investigators of any liability that may result from my participation in this study.

________________________________ ______________

Signature of Investigator **Date**

________________________________ ______________

Signature of Participant **Date**

________________________________ ______________

Signature of Witness **Date**

APPENDIX D

Pre-test Survey

Light Weight Puck Survey

Please answer the following questions about your hockey experience and the use of the lightweight puck:

1. How many seasons have you competed in women's competitive hockey?
   ☐ 1 year ☐ 2 years ☐ 3years ☐ 4 years ☐ 5years ☐ 6 years other __________

2. Prior to playing women's hockey, did you play hockey on a men's team? ☐ yes ☐ no
   If so how many seasons?
   ☐ 1 year ☐ 2 years ☐ 3 years ☐ 4 years ☐ 5 years ☐ 6 years other __________

3. What is the highest age level of women's hockey that you have played?
   ☐ pee wee ☐ atom ☐ novice ☐ initiation ☐ bantam ☐ midget
   ☐ university ☐ senior

4. What is the highest level of women's hockey that you have played?
   ☐ AAA ☐ AA ☐ A ☐ B ☐ CIAU ☐ NCAA
   ☐ other ______________________________

5. What is the highest level of championship that you have participated in?
   ☐ provincial ☐ national ☐ international ☐ other ____________________

6. How many seasons were played at this level?
   ☐ 1 year ☐ 2 years ☐ 3 years ☐ 4 years ☐ 5 years ☐ 6 years other __________

7. Based on your experience, as a player or spectator, what is the most significant difference between men's and women's hockey? (excluding body contact)
   ☐ faster skating ☐ better passing ☐ harder shots ☐ more accurate shots
   ☐ better offense ☐ better defense ☐ better goaltending
   other ____

8. When comparing male to female hockey players, do you thing the majority of females shoot and pass with the same velocity as males? ☐ yes ☐ no
   If so, what are the reasons?
   ☐ males stronger ☐ males play more ☐ males skate faster ☐ males more coordinated ☐ males practice more ☐ males more lessons
   ☐ other ____

9. Do you feel that females can raise the puck with the same velocity and accuracy as male players? ☐ yes ☐ no
   If no, what are the reasons?
   ☐ males stronger ☐ males play more ☐ males skate faster ☐ males more coordinated ☐ males practice more ☐ males more lessons ☐ other ______________

10. Several other female sports have adopted a lighter projectile to enhance the game or improve performances (women's basketball, the shot put etc.). How would you feel about adopting a lighter puck in women's hockey?
    ☐ good idea ☐ bad idea ☐ worth a try ☐ don't care
    ☐ other ____

11. Would you be willing to experiment with a lighter puck in practice? ☐ yes ☐ no
    If no, why not?
    ____

12. Would you be willing to experiment with a lighter puck in a game? ☐ yes ☐ no
    If no, why not? ____

13. Do you feel a lighter puck would enhance the development of shooting and passing skills in women's hockey? ☐ yes ☐ no
    Explain your answer. ____

14. What do you feel would be the advantages of a lighter puck in women's hockey?
    ☐ faster game ☐ faster shots ☐ faster skating ☐ faster passes ☐ higher shots
    ☐ faster goalies ☐ easier to handle
    ☐ other ____

15. What do you feel would be the disadvantages of a lighter puck in women's hockey?
    ☐ game to easy ☐ shots too fast for goalies ☐ shots too high for goalies
    ☐ too light, difficult to handle
    other ____

16. How do you feel women's hockey would be viewed if lighter pucks were used? State any additional comments or concerns you may have on the use of light weight pucks in women's hockey.
    ☐ game too easy ☐ game for weaker sex ☐ not real hockey
    other ____

17. State any additional comments and concerns you may have on the use of light weight pucks in women's hockey. ____
    ____
    ____
    ____

APPENDIX E

Post-test Survey

CANADA

CANADA

POST-TEST SURVEY

1. Did you think that you would enjoy playing with the lighter pucks before this ice session? ☐ yes ☐ no
Explain your answer. ____________________

____

2. Do you prefer the lighter pucks now? ☐ yes ☐ no
Explain your answer? ____________________

____

3. Did it take a long time to adjust to the lighter pucks? ☐ yes ☐ no
Explain your answer? ____________________

____

4. Would you be willing to experiment with a lighter puck in a game? ☐ yes ☐ no If no, why not? ____________________

____

5. The lighter pucks were easier to stick handle than the regulation puck.
☐ strongly disagree ☐ disagree ☐ slightly disagree ☐ no difference
☐ slightly agree ☐ agree ☐ strongly agree

6. The lighter pucks could be shot with a greater velocity than the regulation puck.
☐ strongly disagree ☐ disagree ☐ slightly disagree ☐ no difference
☐ slightly agree ☐ agree ☐ strongly agree

7. The lighter pucks could be raised off the ice more easily than the regulation puck.
☐ strongly disagree ☐ disagree ☐ slightly disagree ☐ no difference
☐ slightly agree ☐ agree ☐ strongly agree

8. Shots with the lighter pucks were more accurate than with the regulation puck.
☐ strongly disagree ☐ disagree ☐ slightly disagree ☐ no difference
☐ slightly agree ☐ agree ☐ strongly agree

9. The lighter pucks could be released more quickly than the regulation puck.
☐ strongly disagree ☐ disagree ☐ slightly disagree ☐ no difference
☐ slightly agree ☐ agree ☐ strongly agree

10. The lighter pucks could be passed with a greater velocity than the regulation puck.
☐ strongly disagree ☐ disagree ☐ slightly disagree ☐ no difference
☐ slightly agree ☐ agree ☐ strongly agree

11. Passes with the lighter pucks were more accurate than the regulation puck.
☐ strongly disagree ☐ disagree ☐ slightly disagree ☐ no difference
☐ slightly agree ☐ agree ☐ strongly agree

12. The lighter pucks could be received more easily than the heavier pucks.
☐ strongly disagree ☐ disagree ☐ slightly disagree ☐ no difference
☐ slightly agree ☐ agree ☐ strongly agree

13. Breakaways were easier to perform with the lighter pucks than the heavier pucks.
☐ strongly disagree ☐ disagree ☐ slightly disagree ☐ no difference
☐ slightly agree ☐ agree ☐ strongly agree

14. Did you feel there was a difference in feel between the light weight pucks and the regulation puck. ☐ yes ☐ no If yes, which of the light weight pucks do you think made the greatest difference with respect to the feel of the puck while playing?
☐ 4.5 oz puck ☐ 5.0 oz puck ☐ 5.5 oz puck

15. Do you feel a lighter puck would enhance the development of shooting and passing skills in women's hockey? ☐ yes ☐ no
Explain your answer. ______________________________

____

16. What do you feel would be the advantages of a lighter puck in women's hockey?
☐ faster game ☐ faster shots ☐ faster skating ☐ faster passes ☐ higher shots
☐ faster goalies ☐ easier to handle
☐ other ______________________________

17. What do you feel would be the disadvantages of a lighter puck in women's hockey?
☐ game too easy ☐ shots too fast for goalies ☐ shots too high for goalies
☐ too light, difficult to handle
☐ other ______________________________

18. If you were to recommend a lighter puck, which would you prefer?
☐ 4.5 oz puck ☐ 5.0 oz puck ☐ 5.5 oz puck

19. How do you feel women's hockey would be viewed if lighter pucks were used? State any additional comments or concerns you may have on the use of light weight pucks in women's hockey.
☐ game too easy ☐ game for weaker sex ☐ not real hockey ☐ games is faster and more well played ☐ enhances women's game ☐ revolution of women's hockey

20. State any additional comments and concerns you may have on the use of light weight pucks in women's hockey. ______________________________

____

APPENDIX F

Ethics Approval

FACULTY OF PHYSICAL EDUCATION AND RECREATION STUDIES

COMMITTEE ON RESEARCH INVOLVING HUMAN SUBJECTS

TITLE OF PROPOSAL:

The effects of the use of a light weight puck on the game of women's hockey.

PRINCIPAL INVESTIGATOR:

Mr. Jeffrey Leiter

SPONSORING AGENCY: in partial fulfilment of the requirements of the M.Sc. Degree

The Committee on Research Involving Human Subjects (Faculty of Physical Education and Recreation Studies) has evaluated the above proposal according to the criteria of the University of Manitoba Committee on Research Involving Human Subjects and finds it to be:

X ____________ acceptable

____________ not acceptable

under the approval category: _____ Approved; __X__ Approved with Modifications; _____Renewal Approved; _____Approved in Principle; _____Tabled; _____Withdrawn; _____Denied

January 27, 2000

Dr. Michael Mahon, Chair

Notes:

APPENDIX G

Individual Data for Wrist Shot Variables

PUCK VELOCITIES									
	4.5 oz puck					5.0 oz puck			
	X (m/s)	Y (m/s)	Z (m/s)	R (m/s)		X (m/s)	Y (m/s)	Z (m/s)	R (m/s)
nat 1a4	17.22		-8.41	19.21	nat1b4	17.41		-7.72	19.1
nat2a2	18.92		-7.22	20.26	nat2b3	17.63		-7.64	19.21
nat3a4	18.98		-9.95	21.46	nat3b3	18.4		-10.03	20.74
nat4a4	19.34		-6.74	20.442	nat4b3	20.37		-8.39	20.37
nat5a4	20.29		-7.61	21.74	nat5b4	19.06		-7.35	20.59
nat6a4	21.03		-7.564	22.35	nat6b4	20.89		-7.87	22.32
nat7a1	19.02		-7.29	19.72	nat7b2	18.22		-7.29	19.72
nat8a5	20.3		-8.36	22	nat8b1	19.87		-10.36	22.44
nat9a4	7.38		-19.18	20.76	nat9b3	8.249		-17.68	19.82
nat10a5	5.38		-18.63	19.82	nat10b4	5.97		-19.32	20.41
nat11a1	5.14		-18.04	19.04	nat11b4	5.9		-15.65	17.22
nat12a4	6.88		-16.91	18.38	nat12b4	6.38		-15.21	16.62
mean	14.99		-11.325	20.432		14.862		-11.209	19.88
std. dev.	6.587		5.158	1.264		6.197		4.470	1.660
	5.5 oz puck					6.0 oz puck			
	X (m/s)	Y (m/s)	Z (m/s)	R (m/s)		X (m/s)	Y (m/s)	Z (m/s)	R (m/s)
nat1c	17.32		-7.769	18.99	nat1d2	17.03		-8.06	18.84
nat2c5	16.85		-8.54	18.64	nat2d5	16.7		-7.7	18.39
nat3c5	18.39		-9.92	21.01	nat3d4	18.17		-7.36	19.72
nat4c5	19.62		-9.69	21.88	nat4d3	19.15		-7.19	20.46
nat5c2	20.28		-7.41	21.54	nat5d4	18.52		-7.91	20.22
nat6c2	20.35		-7.73	21.77	nat6d2	20.38		-7.98	21.9
nat7c1	18.15		-8.55	20.14	nat7d2	18.58		-7.99	20.26
nat8c3	19.32		-7.77	20.97	nat8d3	20.27		-8.35	22.09
nat9c3	8.06		-17.38	19.36	nat9d4	6.73		-15.8	17.4
nat10c5	6.01		-17.96	19.07	nat10d3	6.42		-18.85	20.32
nat11c4	6.63		-16.82	18.43	nat11d3	6.14		-17.35	18.8
nat12c2	4.94		-13.44	14.39	nat12d3	1.94		-14.54	16
mean	14.66		-11.082	19.683		14.169		-10.757	19.533
std. dev.	5.955		4.137	2.087		6.735		4.460	1.758

STICK BLADE ANGULAR DISPLACEMENT, VELOCITY AND TIME														
4.5 oz puck														
Subject	Puck release frame #	Time (s)	Min angle (degrees)	Converted angles	Max angle (degrees)	Converted angles	Difference max ang. - min ang.	Frame #	Time (s)	Differenc e (time)	Max AV	Frame #	Time (s)
nat1a4	32	0.53	106.971	106.97	46.718	46.718	-60.253	34	0.57	0.03	-1511.84	32	0.53
nat2a2	30	0.50	103.814	103.81	38.493	38.493	-65.321	31	0.52	0.02	-1598.14	30	0.50
nat3a4	27	0.45	177.449	177.45	83.598	83.598	-93.851	30	0.50	0.05	-2111.88	27	0.45
nat4a4	31	0.52	175.573	175.57	109.943	109.943	-65.63	34	0.57	0.05	-1421.31	31	0.52
nat5a4	22	0.37	177.218	177.22	71.333	71.333	-105.885	22	0.37	0.00	-2089.15	23	0.38
nat6a4	24	0.40	178.398	178.40	78.829	78.829	-99.569	28	0.47	0.07	-2216.73	25	0.42
nat7a1	21	0.35	177.333	177.33	69.722	69.722	-107.611	25	0.42	0.07	-2077.85	22	0.37
nat8a5	21	0.35	104.443	104.44	31.527	31.527	-72.916	25	0.42	0.07	-1612.1	23	0.38
nat9a4	20	0.33	15.437	164.56	76.996	103.004	-61.559	22	0.37	0.03	-437.21	18	0.30
nat10a5	16	0.27	0.739	179.26	66.101	113.899	-65.362	19	0.32	0.05	-383.39	14	0.23
nat11a1	22	0.37	2.073	177.93	66.353	113.647	-64.28	22	0.37	0.00	-436.63	18	0.30
nat12a4	20	0.33	1.037	178.96	49.197	130.803	-48.16	21	0.35	0.02	-590.7	18	0.30
Mean			101.707		65.734		-75.866				-1373.911		
Std. Dev			77.597		21.673		20.180				722.419		

STICK BLADE ANGULAR DISPLACEMENT, VELOCITY AND TIME													
5.0 oz puck													
Subject	Puck release frame #	Time (s)	Min angle (degrees)	Converted angles	Max angle (degrees)	Converted angles	Difference max ang. - min ang.	Frame #	Time (s)	Difference (time)	Max AV	Frame #	Time (s)
nat1b4	47	0.78	179.129	179.129	99.306	99.306	-79.823	49	0.82	0.03	-2111.78	47	0.78
nat2b3	29	0.48	178.338	178.338	2.97	78.346	-175.3657	32	0.53	0.05	-2431.53	29	0.48
nat3b3	34	0.57	178.012	178.012	73.627	73.627	-104.385	37	0.62	0.05	-2495.8	34	0.57
nat4b3	58	0.97	175.204	175.204	85.836	85.836	-89.368	61	1.02	0.05	-2138.72	58	0.97
nat5b4	13	0.22	172.284	172.284	66.439	66.439	-105.845	13	0.22	0.00	-2371.69	13	0.22
nat6b4	26	0.43	178.435	178.435	97.312	97.312	-81.123	29	0.48	0.05	-2041.81	27	0.45
nat7b2	21	0.35	178.139	178.139	83.759	83.759	-94.38	24	0.40	0.05	-1938.9	22	0.37
nat8b1	24	0.40	107.939	107.939	26.478	26.478	-81.461	26	0.43	0.03	-1966.06	24	0.40
nat9b3	24	0.40	17.444	162.556	85.512	94.488	-68.068	25	0.42	0.02	-595.02	22	0.37
nat10b4	21	0.35	0.46	179.54	73.434	106.566	-72.974	23	0.38	0.03	-435.75	19	0.32
nat11b4	33	0.55	1.238	178.762	63.272	116.728	-62.034	36	0.60	0.05	-633.47	32	0.53
nat12b4	19	0.32	2.648	177.352					0.00	-0.32	-353.59	18	0.30
Mean			114.106	170.474	68.904	84.444	-92.257				-1626.177	28.750	
Std. Dev.			82.711	20.255	29.567	24.207	30.850				849.093	12.800	

Note. Blank cells indicate lost or damaged data.

STICK BLADE ANGULAR DISPLACEMENT, VELOCITY AND TIME													
5.5 oz puck													
Subject	Puck release frame #	Time (s)	Min angle (degrees)	Converted angles	Max angle (degrees)	Converted angles	Difference max ang. - min ang.	Frame #	Time (s)	Difference (time)	Max AV	Frame #	Time (s)
nat1c1	51	0.85	106.971	106.971	46.718	46.718	-60.253	54	0.90	0.05	-1023.23	52	0.87
nat2c5	32	0.53	179.605	179.605	66.18	66.18	-113.425	35	0.58	0.05	-2417.94	33	0.55
nat3c5	38	0.63	178.399	178.399	57.111	57.111	-121.288	41	0.68	0.05	-2659.64	38	0.63
nat4c5	39	0.65	102.372	102.372	42.245	42.245	-60.127	42	0.70	0.05	-880.21	39	0.65
nat5c2	30	0.50	177.712	177.712	76.099	76.099	-101.613	30	0.50	0.00	-1302.42	32	0.53
nat6c2	26	0.43	174.733	174.733	101.943	101.943	-72.79	29	0.48	0.05	-1546.3	27	0.45
nat7c1	26	0.43	178.61	178.61	116.525	116.525	-62.085	29	0.48	0.05	-1035.34	28	0.47
nat8c3	21	0.35	109.879	109.879	24.643	24.643	-85.236	21	0.35	0.00	-1751.16	23	0.38
nat9c3	24	0.40	10.195	169.805	66.423	113.577	-56.228	26	0.43	0.03	-642.65	23	0.38
nat10c5	21	0.35	0.46	179.54	73.434	106.566	-72.974	24	0.40	0.05	-400.9	19	0.32
nat11c4	14	0.23	2.038	177.962	67.984	112.016	-65.946	18	0.30	0.07	-544.72	13	0.22
nat12c2	17	0.28	1.632	178.368	42.175	137.825	-40.543	19	0.32	0.03	-196.6	15	0.25
Mean	28.250		101.884	159.496	65.123	83.454	-76.042				-1200.093		
Std. Dev.	10.481		78.417	32.164	25.743	35.932	24.597				774.253		

STICK BLADE ANGULAR DISPLACEMENT, VELOCITY AND TIME													
6.0oz puck													
Subject	Puck release frame #	Time (s)	Min angle (degrees)	Converted angles	Max angle (degrees)	Converted angles	Difference max ang. - min ang.	Frame #	Time (s)	Difference (time)	Max AV	Frame #	Time (s)
nat1d2	29	0.48	110.32	110.32	41.048	41.048	-69.272	32	0.53	0.05	-1294.16	30	0.50
nat2d5	29	0.48	175.859	175.859	56.54	56.54	-119.319	33	0.55	0.07	-2886.25	29	0.48
nat3d4	38	0.63	179.407	179.407	73.103	73.103	-106.304	41	0.68	0.05	-2595.63	38	0.63
nat4d3	35	0.58	174.537	174.537	94.839	94.839	-79.698	39	0.65	0.07	-2000.22	36	0.60
nat5d4	20	0.33	177.919	177.919	78.552	78.552	-99.367	20	0.33	0.00	-2007.08	21	0.35
nat6d2	20	0.33	175.605	175.605	82.118	82.118	-93.487	24	0.40	0.07	-2355.17	21	0.35
nat7d2	22	0.37	177.745	177.745	117.734	117.734	-60.011	25	0.42	0.05	-953.66		0.00
nat8d3	26	0.43	107.135	107.135	26.664	26.664	-80.471	26	0.43	0.00	-1649.69	26	0.43
nat9d4	21	0.35	15.437	164.563	76.996	103.004	-61.559	17	0.28	-0.07	-468.76	19	0.32
nat10d3	24	0.40	2.585	177.415	69.775	110.225	-67.19	26	0.43	0.03	-466.06	23	0.38
nat11d3	20	0.33	0.958	179.042	67.923	112.077	-66.965	22	0.37	0.03	-576.51	19	0.32
nat12d3	18	0.30	1.133	178.867	42.027	137.973	-40.894	20	0.33	0.03	-410.37	17	0.28
Mean			108.220	164.868	68.943	86.156	-78.711				-1471.96		
Std. Dev.			80.351	26.526	24.945	33.013	22.347				898.848		

Note. Blank cells indicate lost or damaged data.

ANGULAR DISPLACEMENT AND VELOCITY OF THE SHOULDER GIRDLE

4.5 oz puck

Subject	Min angle (degrees)	converted	Max angle (degrees)	converted	Displacement (min. ang. - max. ang).	Frame #	Max. AV (deg/s^2)	Frame #
nat1a4	82.782	82.782	34.039	34.039	-48.743	36	-368.31	33
nat2a2	91.265	91.265	37.456	37.456	-53.809	34	-444.44	25
nat3a4	86.452	86.452	31.964	31.964	-54.488	30	-337.9	28
nat4a4	96.712	96.712	33.538	33.538	-63.174	37	-376.33	25
nat5a4	89.193	89.193	26.019	26.019	-63.174	27	-435.79	22
nat6a4	77.334	77.334	23.056	23.056	-54.278	29	-498.47	23
nat7a1	100.839	100.839	34.693	34.693	-66.146	25	-230.13	15
nat8a5	77.187	77.187	24.25	24.25	-52.937	28	-363.7	20
nat9a4	79.044	99.116	131.727	48.273	-50.843	22	-407.37	16
nat10a5	80.884	80.937	134.388	45.612	-35.325	16	-521.2	12
nat11a1	99.063	80.778	146.079	31.921	-48.857	24	-345.7	19
nat12a4	99.222	91.669	142.332	37.668	-54.001	21	-395.82	17
Mean	88.331	87.655	66.795	34.041	-53.815		-393.763	21.250
Std. Dev	9.000	8.268	53.739	7.697	8.145		77.336	5.972

5.0 oz puck

Subject	Min angle (degrees)	converted	Max angle (degrees)	converted	Displacement (min. ang. - max. ang).	Frame #	Max. AV (deg/s^2)	Frame #
nat1a4	93.747	93.747	36.68	36.68	-57.067	51	-312.64	39
nat2a2	81.565	81.565	36.505	36.505	-45.06	32	-389.85	23
nat3a4	86.476	86.476	32.64	32.64	-53.836	38	-354.35	30
nat4a4	87.907	87.907	33.315	33.315	-54.592	62	-417.6	59
nat5a4	89.405	89.405	33.315	33.315	-56.09	18	-509.05	11
nat6a4	80.495	80.495	28.187	28.187	-52.308	30	-385.29	23
nat7a1	91.934	91.934	34.437	34.437	-57.497	23	-306.73	21
nat8a5	66.787	66.787	21.67	21.67	-45.117	28	-368.47	20
nat9a4	82.262	97.738	125.42	54.58	-43.158	27	-307.95	21
nat10a5	79.52	100.48	140.911	39.089	-61.391	25	-530.72	18
nat11a1	96.389	81.611	146.504	33.496	-48.115	38	-284.73	27
nat12a4	94.084	85.916	135.71	44.29	-41.626	22	-345.43	15
Mean	86.048	87.005	67.108	35.684	-51.321		-376.067	25.583
Std. Dev	8.552	8.967	52.082	8.112	6.480		77.977	12.745

ANGULAR DISPLACEMENT AND VELOCITY OF THE SHOULDER GIRDLE

	5.5 oz puck								6.0 oz puck							
Subject	Min angle (degrees)	converted	Max angle (degrees)	converted	Displacement (min. ang. - max. ang).	Frame #	Max. AV (deg/s²)	Frame #	Min angle (degrees)	converted	Max angle (degrees)	converted	Displacement (min. ang. - max. ang).	Frame #	Max. AV (deg/s²)	Fram
nat1a4	85.808	85.808	39.887	39.887	-45.921	54	-274.08	53	82.996	82.996	41.707	41.707	-41.289	32	-307.3	26
nat2a2	87.121	87.121	29.073	29.073	-58.048	35	-439.5	29	80.792	80.792	36.269	36.269	-44.523	33	-332.84	24
nat3a4	89.985	89.985	25.542	25.542	-64.443	42	-356.68	34	82.934	82.934	32.412	32.412	-50.522	42	-271.77	37
nat4a4	88.481	88.481	34.842	34.842	-53.639	45	-569.05	39	82.554	82.554	36.425	36.425	-46.129	37	-473.02	35
nat5a4	89.068	89.068	28.694	28.694	-60.374	33	-418.87	29	101.06	101.06	33.048	33.048	-68.012	27	-413.22	19
nat6a4	73.957	73.957	25.692	25.692	-48.265	29	-368.93	22	77.41	77.41	29.093	29.093	-48.317	24	-321.85	16
nat7a1	102.713	102.713	35.555	35.555	-67.158	29	-604.4	23	91.691	91.691	31.729	31.729	-59.962	25	-476.71	20
nat8a5	75.37	75.37	26.182	26.182	-49.188	27	-522.95	19	81.616	81.616	28.905	28.905	-52.711	30	-429.46	21
nat9a4	82.728	97.272	131.102	48.898	-48.374	27	-288.316	20	82.815	97.185	129.007	50.993	-46.192	22	-359.709	16
nat10a5	90.398	89.602	148.012	31.988	-57.614	22	-429.09	18	75.471	104.529	146.27	33.73	-70.799	28	-572.4	20
nat11a1	95.662	84.338	144.936	35.064	-49.274	18	-405.952	13	88.702	91.298	146.059	33.941	-57.357	23	-361.379	17
nat12a4	106.629	73.371	139.891	40.109	-33.262	21	-355.96	14	94.493	85.507	138.92	41.08	-44.427	20	-587.02	13
Mean	88.993	86.424	67.451	33.461	-52.963		-419.482	26.083	85.211	88.298	69.154	35.778	-52.520		-408.890	22.00
Std. Dev	9.589	8.894	54.616	7.089	9.268		103.057	11.548	7.401	8.754	52.653	6.253	9.587		102.149	7.44

LINEAR DISPLACEMENT
OF C OF G

	4.5 oz puck (meters)											
Subject	X(min)	X(max)	Difference	Y(min)	Y(max)	Difference	Z(min)	Z(max)	Difference	R(min)	R(max)	Difference
nat 1a4	-0.583	-0.023	0.56	2.104	1.978	-0.126	-0.475	-0.58	-0.105	2.242	2.059	-0.183
nat2a2	-1.059	-0.715	0.344	2.082	2.17	0.088	-0.309	-0.399	-0.09	2.389	2.291	-0.098
nat3a4	-0.717	-0.378	0.339	1.729	1.665	-0.064	-0.399	-0.521	-0.122	1.915	1.785	-0.13
nat4a4	-1.249	-0.698	0.551	2.257	2.165	-0.092	-0.269	-0.391	-0.122	2.604	2.308	-0.296
nat5a4	-1.109	-0.667	0.442	1.727	1.612	-0.115	-0.317	-0.417	-0.1	2.802	1.801	-1.001
nat 6b4												
nat7a1	-1.517	-1.777	-0.26	2.066	2.124	0.058	-0.254	-0.325	-0.071	2.576	2.447	-0.129
nat8a5	-0.865	-0.266	0.599	2.293	2.091	-0.202	-0.378	-0.455	-0.077	2.481	2.156	-0.325
nat9a4	-0.219	-0.074	0.145	0.717	0.682	-0.035	0.415	-0.051	-0.466	0.856	0.7	-0.156
nat10a5	0.264	0.304	0.04	0.715	0.759	0.044	0.655	0.317	-0.338	1.008	0.876	-0.132
nat11a1	-0.257	-0.07	0.187	0.662	0.708	0.046	0.827	0.503	-0.324	1.097	0.872	-0.225
nat12a4	0.19	0.339	0.149	0.668	0.644	-0.024	0.395	0.039	-0.356	0.799	0.719	-0.08
Mean	-0.647	-0.366	0.281	1.547	1.509	-0.038	-0.010	-0.207	-0.197	1.888	1.638	-0.250
Std. Dev	0.585	0.597	0.261	0.702	0.669	0.091	0.480	0.359	0.143	0.787	0.701	0.261

LINEAR DISPLACEMENT OF
C OF G

				5.0 oz puck (meters)								
Subject	X(min)	X(max)	Difference	Y(min)	Y(max)	Difference	Z(min)	Z(max)	Difference	R(min)	R(max)	Difference
nat 1a4	-0.845	-0.267	0.578	2.123	1.795	-0.328	-0.443	-0.562	-0.119	2.305	1.899	-0.406
nat2a2	-1.153	-0.804	0.349	2.138	2.074	-0.064	-0.308	-0.387	-0.079	2.455	2.258	-0.197
nat3a4	-0.656	-0.306	0.35	1.813	1.753	-0.06	-0.402	-0.5	-0.098	1.964	1.849	-0.115
nat4a4	-1.13	-0.5	0.63	2.295	2.164	-0.131	-0.273	-0.457	-0.184	2.586	2.268	-0.318
nat5a4	-1.182	-0.858	0.324	1.612	1.491	-0.121	-0.305	-0.388	-0.083	2.022	1.763	-0.259
nat 6b4	-0.803	-0.284	0.519	2.097	2.037	-0.06	-0.457	-0.547	-0.09	2.27	2.129	-0.141
nat7a1	-1.28	-0.904	0.376	1.834	1.878	0.044	-0.336	-0.396	-0.06	2.262	2.119	-0.143
nat8a5	-1.093	-0.582	0.511	2.415	2.281	-0.134	-0.353	-0.391	-0.038	2.67	2.386	-0.284
nat9a4	0.019	0.182	0.163	0.723	0.685	-0.038	0.552	0.081	-0.471	0.91	0.731	-0.179
nat10a5	0.314	0.439	0.125	0.702	0.741	0.039	0.802	0.435	-0.367	1.126	0.964	-0.162
nat11a1	-0.002	0.081	0.083	0.69	0.744	0.054	0.629	0.311	-0.318	0.951	0.808	-0.143
nat12a4	0.04	0.192	0.152	0.651	0.624	-0.027	0.234	-0.173	-0.407	0.693	0.637	-0.056
Mean	-0.648	-0.301	0.347	1.591	1.522	-0.069	-0.055	-0.248	-0.193	1.851	1.651	-0.200
Std. Dev.	0.579	0.449	0.186	0.698	0.642	0.105	0.470	0.340	0.154	0.722	0.668	0.099

Note. Blank cells indicate lost or damaged data

LINEAR DISPLACEMENT

OF C OF G

	5.5 oz puck (meters)											
	X(min)	X(max)	Difference	Y(min)	Y(max)	Difference	Z(min)	Z(max)	Difference	R(min)	R(max)	Difference
nat1c1	-1.076	-0.568	0.508	2.086	1.848	-0.238	-0.386	0.478	0.864	2.348	1.922	-0.426
nat2c5	-0.967	0.598	1.565	1.921	1.832	-0.089	-0.332	-0.462	-0.13	2.174	1.981	-0.193
nat3c5	-0.607	-0.192	0.415	1.711	1.617	-0.094	-0.432	-0.573	-0.141	1.866	1.725	-0.141
nat4c5	-1.008	-0.491	0.517	2.227	2.059	-0.168	-0.337	-0.452	-0.115	2.472	2.164	-0.308
nat5c2	-1.142	-0.811	0.331	2.108	1.833	-0.275	-0.309	-0.403	-0.094	2.423	2.045	-0.378
nat6c2	-0.951	-0.451	0.5	2.046	1.933	-0.113	-0.414	-0.496	-0.082	2.273	2.103	-0.17
nat7c1	-1.476	-0.973	0.503	2.747	2.678	-0.069	-0.249	-0.307	-0.058	3.128	2.864	-0.264
nat8c3	-0.851	-0.285	0.566	2.398	2.282	-0.116	-0.391	-0.453	-0.062	2.568	2.344	-0.224
nat9c3	-0.109	0.055	0.164	0.725	0.69	-0.035	0.426	-0.103	-0.529	0.848	0.695	-0.153
nat10c5	0.56	0.739	0.179	0.699	0.765	0.066	0.93	0.479	-0.451	1.296	1.159	-0.137
nat11c4	-0.055	0.001	0.056	0.655	0.688	0.033	0.563	0.245	-0.318	0.869	0.73	-0.139
nat12c2	0.292	0.43	0.138	0.658	0.63	-0.028	0.108	-0.24	-0.348	0.728	0.813	0.085
Mean	-0.616	-0.162	0.454	1.665	1.571	-0.094	-0.069	-0.191	-0.122	1.916	1.712	-0.204
Std. Dev.	0.636	0.545	0.392	0.766	0.701	0.100	0.463	0.382	0.350	0.791	0.702	0.133

LINEAR DISPLACEMENT OF

C OF G

Subject	X(min)	X(max)	Difference	Y(min)	Y(max)	Difference	Z(min)	Z(max)	Difference	R(min)	R(max)	Difference
				6.0 oz puck (meters)								
nat1d2	-0.89	-0.391	0.499	2.176	1.923	-0.253	-0.407	-0.5	-0.093	2.189	1.88	-0.309
nat2d5	-0.81	-0.447	0.363	1.984	1.9	-0.084	-0.396	-0.48	-0.084	-0.81	-0.447	0.363
nat3d4	-0.732	-0.362	0.37	1.943	1.866	-0.077	-0.386	-0.477	-0.091	2.115	1.959	-0.156
nat4d3	-1.151	-0.75	0.401	2.249	2.165	-0.084	-0.31	-0.385	-0.075	2.541	2.323	-0.218
nat5d4	-1.206	-0.817	0.389	1.741	1.534	-0.207	-0.283	-0.364	-0.081	2.137	1.775	-0.362
nat6d2	-0.869	-0.422	0.447	2.02	1.962	-0.058	-0.425	-0.525	-0.1	2.23	2.075	-0.155
nat7d2	-1.261	-0.841	0.42	2.331	2.417	0.086	-0.279	-0.335	-0.056	2.673	2.58	-0.093
nat8d3	-0.879	-0.321	0.558	2.848	2.579	-0.269	-0.332	-0.403	-0.071	3.002	2.63	-0.372
nat9d4	0.242	0.359	0.117	0.69	0.711	0.021	0.171	-0.148	-0.319	0.747	0.812	0.065
nat10d3	0.591	0.746	0.155	0.684	0.749	0.065	1.028	0.475	-0.553	1.324	1.155	-0.169
nat11d3	-0.192	-0.024	0.168	0.656	0.728	0.072	0.72	0.361	-0.359	1	0.812	-0.188
Nat12d3	0.196	0.334	0.138	0.661	0.644	-0.017	0.205	-0.109	-0.314	0.701	0.739	0.038
Mean	-0.552	-0.231	0.321	1.619	1.569	-0.050	-0.026	-0.217	-0.191	1.605	1.492	-0.113
Std. Dev.	0.650	0.525	0.149	0.801	0.736	0.113	0.499	0.340	0.167	1.128	0.958	0.208

Appendix H

Individual Data for the Hockey Skill Tests

ACCURACY SHOOT

	4.5 oz puck									5.0 oz puck								
	1	2	3	4	5	6	Hits	Shots	Shooting %	1	2	3	4	5	6	Hits	Shots	Shooting %
Player #7r	s	s	s	s	s	h	1	6	17%	s	s	s	h	h	s	2	6	33%
38b	h	s	s	s	h	s	2	6	33%	s	s	s	h	s	s	1	6	17%
35b	s	s	s	s	h	h	2	6	33%	s	s	h	s	s	s	1	6	17%
30b	s	s	h	s	s	h	2	6	33%	s	h	h	s	s	h	3	6	50%
37b	s	s	s	s	s	s	0	6	0%	s	s	h	s	h	s	2	6	33%
29b	s	h	s	h	h	h	4	6	67%	s	s	s	h	s	h	2	6	33%
4w	s	h	s	s	h	s	2	6	33%	s	s	s	h	s	h	2	6	33%
5w	s	h	s	s	s	s	1	6	17%	s	s	h	h	s	s	2	6	33%
5r	s	s	s	s	s	h	1	6	17%	s	s	s	s	h	h	2	6	33%
10w	h	s	s	h	h	s	3	6	50%	s	h	h	h	h	h	5	6	83%
6w	s	h	s	s	s	h	2	6	33%	s	s	s	s	h	s	1	6	17%
8w	s	s	h	s	h	h	3	6	50%	s	s	s	s	h	s	1	6	17%
4r	s	s	s	h	h	s	2	6	33%	s	s	h	s	s	s	1	6	17%
1r	s	h	s	s	s	s	1	6	17%	s	h	s	s	s	s	1	6	17%
2r	s	s	h	h	s	s	2	6	33%	h	s	s	s	s	h	2	6	33%
2w	h	s	s	s	h	s	2	6	33%	h	s	s	s	s	h	2	6	33%
31b	s	h	h	s	h	s	3	6	50%	s	h	h	s	h	h	4	6	67%
34b	s	s	s	s	s	h	1	6	17%	h	h	h	h	s	s	4	6	67%
33b	h	h	h	s	s	h	4	6	67%	s	s	s	s	s	h	1	6	17%
32b	h	s	h	s	s	h	3	6	50%	s	s	s	s	s	h	1	6	17%
36b	h	s	s	s	s	h	2	6	33%	h	s	s	s	s	s	1	6	17%
3r	s	s	s	s	h	s	1	6	17%	h	s	s	s	s	h	2	6	33%
6r	s	h	s	s	s	s	1	6	17%	s	h	h	s	s	s	2	6	33%
Mean							2	6	33%							2	6	33%
Std. Dev.							1	0	17%							1.1	0	18%

* percentage scores are rounded to the nearest percent

ACCURACY SHOOT																			
	5.5 oz puck									6.0 oz puck									
	1	2	3	4	5	6	Hits	Shots	Shooting %	1	2	3	4	5	6	Hits	Shots	Shooting %
Player #7r	h	s	s	s	s	h	2	6	33%	s	s	h	s	s	h	2	6	33%
38b	h	s	h	s	h	s	3	6	50%	s	s	s	s	s	s	0	6	0%
35b	s	s	h	h	h	h	4	6	67%	s	s	s	h	s	s	1	6	17%
30b	s	s	h	h	s	s	2	6	33%	h	s	h	s	s	h	3	6	50%
37b	s	s	s	s	s	s	0	6	0%	h	s	h	s	s	h	3	6	50%
29b	h	s	s	h	s	h	3	6	50%	s	s	s	s	s	h	1	6	17%
4w	h	h	s	s	s	s	4	6	67%	s	h	s	s	s	s	2	6	33%
5w	s	h	s	s	s	s	1	6	17%	s	s	s	s	s	h	1	6	17%
5r	s	s	s	s	s	s	0	6	0%	s	s	s	s	h	s	1	6	17%
10w	s	s	s	s	h	s	1	6	17%	h	h	h	h	s	s	4	6	67%
6w	h	s	h	h	s	s	3	6	50%	s	s	s	s	s	s	0	6	0%
8w	s	h	s	s	s	s	1	6	17%	h	s	h	s	h	s	3	6	50%
4r	s	s	s	s	s	s	0	6	0%	s	s	s	s	s	s	6	6	100%
1r	s	s	h	s	s	h	2	6	33%	s	s	s	s	s	s	6	6	100%
2r	s	s	h	s	h	s	2	6	33%	h	s	s	s	s	s	1	6	17%
2w	s	h	h	h	s	s	3	6	50%	s	s	s	s	s	s	0	6	0%
31b	s	h	h	h	h	s	4	6	67%	h	s	h	h	s	s	3	6	50%
34b	h	s	s	h	s	h	3	6	50%	s	s	h	s	s	s	1	6	17%
33b	s	h	h	h	h	h	5	6	83%	s	s	s	s	h	h	2	6	33%
32b	s	s	h	s	s	s	1	6	17%	s	s	s	h	s	h	2	6	33%
36b	s	s	h	s	s	s	1	6	17%	s	s	s	s	h	s	1	6	17%
3r	h	s	s	h	s	s	2	6	33%	s	s	s	s	s	h	1	6	17%
6r	h	s	s	s	h	s	2	6	33%	h	s	s	h	s	s	2	6	33%
Mean							2.1	6	36%							2	6	33%
Std. Dev.							1.4	0	23%							1.7	0	28%

* percentage scores are rounded to the nearest percent

PUCKHANDLING				
	4.5 oz puck	5.0 oz puck	5.5 oz puck	6.0 oz puck
	Trial 1	Trial 1	Trial 1	Trial 1
Player #7r	13.09	12.69	12.72	13.28
38b	13.66	13.47	13.82	14.94
35b	13.47	13.22		13.5
30b	13.96	13.37	13.54	12.94
37b	13.87	14.4	14.12	14.25
29b	13.81	15.97	13.41	13.5
4w	13.79	14.18	13.94	14.37
5w	13.59	14.09	13.53	13.57
5r	14.32	13.56	14.29	14.09
10w	14.16	14.03	14.12	13.94
6w	13.13	13.12	13.34	13.09
8w	13.5		13.53	13.34
4r	13.81	13.28	13.16	13.16
1r	13.69	13.41	13.43	13.65
2r	12.69	13.25		12.68
2w	12.87	13.22	13.38	13
31b	13.25	13.03	13	
34b	13.13	13.18	13.53	13.19
33b	13.85	13.84	13.44	13.69
32b	13.28	13.16	13.03	12.65
36b	13.91	13.66	13.31	13.37
3r	12.59	12.78	12.69	14.41
6r	13.03		12.65	13.28
Mean	13.50	13.57	13.43	13.54
Std. Dev	0.46	0.71	0.46	0.59

Note. empty cell is a deleted time as player lost puck during trial

RAPID FIRE

4.5 oz puck

Player	1	2	3	4	5	goals	saves	misses	shooting%	save%	miss%
Player #7r	s	s	s	s	s	0	5	0	0%	100%	0%
38b	s	m	m	m	g	1	1	3	20%	20%	60%
35b	g	m	s	g	m	2	1	2	40%	20%	40%
30b	g	s	g	m	s	2	2	1	40%	40%	20%
37b	s	s	s	s	s	0	5	0	0%	100%	0%
29b	s	m	s	s	m	0	3	2	0%	60%	40%
4w	m	s	m	s	g	1	2	2	20%	40%	40%
5w	s	g	g	m	g	3	1	1	60%	20%	20%
5r	s	m	s	s	s	0	4	1	0%	80%	20%
10w	g	s	g	s	g	3	2	0	60%	40%	0%
6w	s	g	g	m	m	2	1	2	40%	20%	40%
8w	s	s	m	s	s	0	4	1	0%	80%	20%
4r	x	x	x	x	x	x	x	x			
1r	x	x	x	x	x	x	x	x			
2r	x	x	x	x	x	x	x	x			
2w	x	x	x	x	x	x	x	x			
31b	x	x	x	x	x	x	x	x			
34b	x	x	x	x	x	x	x	x			
33b	x	x	x	x	x	x	x	x			
32b	x	x	x	x	x	x	x	x			
36b	x	x	x	x	x	x	x	x			
3r	x	x	x	x	x	x	x	x			
6r	x	x	x	x	x	x	x	x			
Mean									23%	52%	25%
Std. Dev.									24%	31%	19%

5.0 oz puck

Player	1	2	3	4	5	goals	saves	misses	shooting%	miss%
Player #7r	m	s	s	s	s	0	4	1	0	20%
38b	s	m	s	s	m	0	3	2	0%	40%
35b	m	s	s	s	s	0	4	1	0%	20%
30b	g	g	m	g	g	4	0	1	80%	20%
37b	g	s	m	s	s	1	1	3	20%	60%
29b	s	m	s	s	m	0	3	2	0%	40%
4w	m	s	s	g	s	1	3	1	20%	20%
5w	s	m	m	m	s	0	2	3	0%	60%
5r	s	g	g	s	s	2	3	0	40%	0%
10w	m	s	g	m	s	1	2	2	20%	40%
6w	s	s	s	m	g	1	3	1	20%	20%
8w	m	g	g	s	s	2	2	1	40%	20%
4r	x	x	x	x	x	x	x	x		
1r	x	x	x	x	x	x	x	x		
2r	x	x	x	x	x	x	x	x		
2w	x	x	x	x	x	x	x	x		
31b	x	x	x	x	x	x	x	x		
34b	x	x	x	x	x	x	x	x		
33b	x	x	x	x	x	x	x	x		
32b	x	x	x	x	x	x	x	x		
36b	x	x	x	x	x	x	x	x		
3r	x	x	x	x	x	x	x	x		
6r	x	x	x	x	x	x	x	x		
Mean									20%	30%
Std. Dev.									24%	18%

x = missed trial because goalie was injured

s = save by goalie

g = goal by player

m = shot missed the net

*percentage scores are rounded to the nearest percent

RAPID FIRE

5.5 oz puck

	1	2	3	4	5	goals	saves	misses	shooting%	save%	miss%
Player #7r	s	s	s	m	s	0	4	1	0%	80%	20%
38b	s	s	g	m	m	1	2	2	20%	40%	40%
35b	g	s	g	m	s	2	2	1	40%	40%	20%
30b	g	g	g	g	m	4		1	80%	0%	20%
37b	m	s	m	m	s	0	2	3	0%	40%	60%
29b	s	m	s	s	m	0	3	2	0%	60%	40%
4w	g	s	s	s	s	1	4		20%	80%	0%
5w	s	g	s	g	s	2	3		40%	60%	0%
5r	m	s	s	s	s		4	1	0%	80%	20%
10w	m	s	s	g	g	2	2	1	40%	40%	20%
6w	s	g	s	g	s	2	3		40%	60%	0%
8w	s	s	s	s	s	0	5		0%	100%	0%
4r	x	x	x	x	x	x	x	x			
1r	x	x	x	x	x	x	x	x			
2r	x	x	x	x	x	x	x	x			
2w	x	x	x	x	x	x	x	x			
31b	x	x	x	x	x	x	x	x			
34b	x	x	x	x	x	x	x	x			
33b	x	x	x	x	x	x	x	x			
32b	x	x	x	x	x	x	x	x			
36b	x	x	x	x	x	x	x	x			
3r	x	x	x	x	x	x	x	x			
6r	x	x	x	x	x	x	x	x			
Mean									23%	57%	20%
Std. Dev.									25%	27%	19%

6.0 oz puck

	1	2	3	4	5	goals	saves	misses	shooting%	save%	miss%
Player #7r	s	g	s	s	s	1	4	0	20%	80%	0%
38b	s	m	s	m	m	0	2	3	0%	40%	60%
35b	s	s	s	g	s	1	4	0	20%	80%	0%
30b	s	s	s	m	s	0	4	1	0%	80%	20%
37b	s	s	m	s	s	0	4	1	0%	80%	20%
29b	g	g	s	m	s	2	2	1	40%	40%	20%
4w	s	s	m	s	g	1	2	2	20%	40%	40%
5w	s	s	s	m	m	0	3	2	0%	60%	40%
5r	s	s	s	m	s	0	4	1	0%	80%	20%
10w	s	s	s	s	s	0	5	0	0%	100%	0%
6w	g	s	g	g	s	3	2	0	60%	40%	0%
8w	s	s	s	s	m	0	4	1	0%	80%	20%
4r	x	x	x	x	x	x	x	x			
1r	x	x	x	x	x	x	x	x			
2r	x	x	x	x	x	x	x	x			
2w	x	x	x	x	x	x	x	x			
31b	x	x	x	x	x	x	x	x			
34b	x	x	x	x	x	x	x	x			
33b	x	x	x	x	x	x	x	x			
32b	x	x	x	x	x	x	x	x			
36b	x	x	x	x	x	x	x	x			
3r	x	x	x	x	x	x	x	x			
6r	x	x	x	x	x	x	x	x			
Mean									13%	67%	4%
Std. Dev.											

x = missed trial because goalie was injured
g = goal by player
*percentage scores are rounded to the nearest percent
s = save by goalie
m = shot missed the net

BREAKAWAYS												
	4.5 oz puck		5.0 oz puck		5.5 oz puck		6.0 oz puck				Individual	Individual
	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2	Saves	Goals	Save %	Shooting %
Player #7r	S	G	S	S	S	G	S	S	6	2	75%	25%
38b												
35b												
30b												
37b												
29b												
4w												
5w												
5r	S	S	S	S	S	S	S	S	8	0	100%	0%
10w												
6w												
8w												
4r	S	S	S	S	S	S	G	S	7	1	88%	13%
1r	S	S	S	S	S	S	S	S	8	0	100%	0%
2r	S	S	S	G	S	G	G	S	5	3	63%	38%
2w	G	S	G	S	S	S	S	S	6	2	75%	25%
31b	S	S	S	S	G	S	S	S	7	1	88%	13%
34b	G	S	S	S	S	S	S	S	7	1	88%	13%
33b	S	S	G	S	G	S	S	S	6	2	75%	25%
32b	S	S	S	S	S	S	S	G	7	1	88%	13%
36b	G	S	S	S	S	S	S	S	7	1	88%	13%
3r	S	S	S	G	G	S	S	S	6	2	75%	25%
6r	S	G	S	S	S	S	S	S	7	1	88%	13%
Total Saves	10	11	11	11	10	11	11	12	87			
Total Goals	3	2	2	2	3	2	2	1		17		
Shooting %	23%	15%	15%	15%	23%	15%	15%	8%				
Save %	77%	85%	85%	85%	77%	85%	85%	92%				

* percentage scores are rounded to the nearest percent.
S = save G = goal
blank cell symbolizes missed trial as goalie was injured

APPENDIX I

Individual Data for Pre and Post-test Surveys

PRE TEST RESULTS

1. How many seasons have you competed in the women's competitive hockey?

Years	U22		NWT	
1	1	4%		
2	1	4%		
3	3	12%		
4	5	20%		
5	3	12%		
6	7	28%		
7	2	8%	1	8%
8	1	4%		0%
9				0%
10			1	8%
11			1	8%
12			1	8%
13			1	8%
14				0%
15			2	17%
16				0%
17			2	17%
18				0%
19			2	17%
20			1	8%

2 Prior to playing women's hockey, did you play hockey on a men's team? If so, how many seasons?

	U22	NWT
yes	22	10
no	3	2

Years	U22		NWT	
1			1	8%
2				0%
3	1	4%	1	8%
4	1	4%		0%
5	2	8%	1	8%
6	2	8%	2	17%

7		0%	2	17%
8	6	24%	2	17%
9	3	12%		0%
10	2	8%	1	8%
11	1	4%		
12	2	8%		
13	1	4%		

3 What is the highest age level of women's hockey that you have played?

Level	U22		NWT	
pee wee				0%
atom		0%		0%
novice		0%		0%
initiation		0%		0%
bantam		0%	1	8%
midget	1	4%		0%
university	9	36%	1	8%
senior	15	60%	10	83%

4 What is the highest level of women's hockey that you have played?

Level	U22		NWT	
AAA	9	36%	3	25%
AA		0%		0%
A		0%		0%
B		0%		0%
CIAU	4	16%		0%
NCAA	7	28%	2	17%
National	4	16%	2	17%
Int./Olympic			5	42%

5 What is the highest level of championship that you participated in?

Level	U22		NWT	
provincial	2	8%		
national	13	52%	4	33%
international	10	40%	8	67%
western shield				
CIAU				

6 How many seasons were played at this level?

Years	U22		NWT	
1	11	44%	2	17%
2	7	28%	1	8%
3	3	12%	1	8%
4	1	4%	1	8%
5	1	4%		0%
6	1	4%	2	17%
7			1	8%
8			1	8%
9			1	8%
10			2	17%

7 Based on your experience, as a player or a spectator, what is the most siginificant difference between men's and women's hockey? (excluding body contact)

Reasons	U22		NWT	
faster skating	12	48%	7	58%
better passing	8	32%	4	33%
harder shots	11	44%	11	92%
more accurate shots		0%	1	8%
better offense		0%		
better defense		0%		
better goaltending		0%		
other:				
more technical				

and intense	1	4%		
better passing in women's	1	4%		
worse temper, men stronger			1	8%

8 When comparing male to female hockey players, do you think the majority of females shoot and pass with the same velocity as males?

response	U22		NWT	
yes	2	8%		
no	22	88%	12	100%

reasons	U22		NWT	
males stronger	22	88%	12	100%
males play more		0%		0%
males skate faster	3	12%		0%
males more coordinated		0%		0%
males practice more		0%		0%
males more lessons		0%		0%
other:		0%		
physical build,				0%
longer levers	1	4%	1	8%

9 Do you feel that females can raise the puck with the same velocity and accuracy as male players? If no, what are the reasons?

response	U22		NWT	
yes	6	24%	1	8%
no	18	72%	11	92%
velocity yes, accuracy no	1	4%		

reasons	U22		NWT	
males stronger	19	76%	11	92%
males play more				0%
males skate faster			1	8%
males more coordinated				0%
males practice more				0%
males more lessons				0%
other:				0%
physical size			1	8%

10 Several other female sports have adopted a lighter projectile to enhance the game or improve performances (women's basketball, shot put etc.). How would you feel about adopting a lighter puck in women's hockey.

responses	U22		NWT	
good idea	1	4%	5	42%
bad idea	6	24%		0%
worth a try	12	48%	6	50%
don't care	5	20%	1	8%
other:				
don't think it is needed	1	4%		
not sure	1	4%		

11 Would you be willing to experiment with lighter puck in practice? If no, why not?

	U22		NWT	
yes	24	96%	12	100%
no	1	4%		
reasons				
if you practice with a light puck you won't get used to it	1	4%		

12 Would you be willing to experiment with a lighter puck in a game? If no, why not?

	U22		NWT	
no	4	16%	12	100%
yes	19	76%		
don't know	2	8%		
reasons				
after we practice with it	1	4%		
it would change what we have been doing for so long	1	4%		

because it will not be the same	1	4%
should be the same for all, not change for females	1	4%

13 Do you think a lighter puck would enhance the development of shooting and passing skills in women's hockey?

responses	U22		NWT	
yes	13	52%	11	92%
no	9	36%		0%
maybe/ undecided	2	8%	1	8%
reasons				
it will make the game faster	3	12%	1	8%
it would simply make it harder faster, not enhance development	1	4%		
doesn't take as much effort	1	4%		
faster shots	1	4%		
I have not seen or used it yet	1	4%		
I don't think it will improve accuracy, just velocity	1	4%		
faster passes and harder shots	1	4%		
not needed we are strong enough	1	4%		
upper bodies aren't as strong			3	25%
women have correct technique but are not as strong as males			1	8%

14 What do you feel would be the advantages of a lighter puck in women's hockey?

responses	U22		NWT	
faster game	9	36%	4	33%
faster shots	18	72%	12	100%

faster skating	1	4%		0%
faster passes	10	40%	10	83%
higher shots	5	20%	1	8%
faster goalies	1	4%	2	17%
easier to handle	3	12%	1	8%

15 What do you feel would be the disadvantages of a lighter puck in women's hockey?

responses	U22		NWT	
game too easy		0%		0%
shots too fast for goalies	2	8%		0%
shots too high for goalies	3	12%	1	8%
too light, difficult to handle	15	60%	9	75%
other:				
don't feel there are any	1	4%		
it would be perceived as not real hockey	1	4%		
not as much respect from others	1	4%		
public image, especially as viewed by men	1	4%		
wouldn't look good to eyes of skeptics	1	4%	1	8%
too much of a change	1	4%		
good for younger players but may be too difficult to adjust to			1	8%
may be too bouncy			1	8%

16 How do you feel women's hockey would be viewed if lighter pucks were used?

responses	U22		NWT	
game too easy	1	4%		
game for weaker sex	16	64%	5	42%
not real hockey	11	44%	1	8%
other:				

a lot of different opinions	1	4%		
too much of a change	1	4%		
it wouldn't be viewed differently	1	4%	1	8%
making it easier for women	1	4%		
the same	1	4%		
good idea to increase speed			1	8%
Just the same as basketball, I don't think it would be negative			1	8%
Don't care what people think if it makes the game better			1	8%
create a greater divide between men's and women's			1	8%

17 State any additional comments and concerns you may have on the use of light weight pucks in women's hockey.

	U22		NWT	
I think it gives women the persona as being weak and unable to play hockey in the original way	1	4%		
I think we are not having problems with normal pucks and there is no reason to change	2	8%		
negative reaction from public	1	4%		
Good idea	1	4%		
I don't think we need or want to be like men. I think our game is good.	1	4%		
inconsistency of product			1	8%
I think that a lighter puck could make or break the game.			1	8%

in different situations.	1	8%
The bounces off boards and the fluttering of puck when shot. I loved the 5.0 oz puck, it wasn't too light but a noticeable difference. The 5.5 oz was hard to notice a difference and the 4.5 oz puck was too light.	1	8%
Need to try in games and practices.	1	8%
I am not sure how I feel about it quite yet. I feel it would change the perceptionof the game. It might bring a negative view but other woman's sports have used it. It is worth try if it increases speed and accuracy of the shots on net and control of the puck.	1	8%

POST TEST RESULTS

1 Did you think that you would enjoy playing with the lighter pucks before this ice session? Explain your answer.

responses	U22		NWT	
yes	14	56%	8	67%
no	8	32%	4	33%
reasons				
my shot could use a little help	1	4%		
could have adjusted better	1	4%		
didn't really form a definite opinion	1	4%		
because I think they will improve the women's game	1	4%		
because it is too light	2	8%		
fun to try, see how hard can shoot	3	12%		
Change the game, I like the way it is	1	4%		
would be interesting, different	3	12%		
good experience and fun	2	8%		
fun too pick the top corner every time	1	4%		
makes us look weak	1	4%		
too light and not needed always liked the regular puck	1	4%		
I thought it would make everything easier	1	4%		
I am not as strong as the others so it would give me advantage			1	8%
Because with a lighter puck - I think I would have better				

technique, more control and a faster shot	1	8%
Never had the opportunity to try it.	1	8%
A new way to improve the game.	1	8%
I want to do everything to improve women's hockey.	1	8%
I thought I would be uncomfortable with the weight	1	8%
I wasn't sure about it.	1	8%
Skeptical at first but after trying the lighter puck I think it would be worth a try.	1	8%
I was skeptical but for certain weights I didn't see a big difference.	1	8%
I think it will make the game quicker.	1	8%

2 Do you prefer the lighter pucks now? Explain your answer.

responses	U22		NWT	
yes	8	32%	7	58%
no	15	60%	1	8%
maybe/undecided	1	6%	4	33%

reasons		
easier to shoot with but harder to handle, pass, etc.	1	4%
shots seemed a lot quicker and harder	1	4%
makes shooting easier	1	4%
too light to handle, too bouncy	3	12%

yes, 5.0 or 5.5	2	8%		
faster	1	4%		
too light (4.5 oz) went everywhere	2	8%		
it's fun but I didn't have a preferenc e	1	4%		
passing the 4.5 oz was too light, but they were O.K. for stickhandling and shooting	1	4%		
5.5 oz is good, other are too bouncy	2	8%		
it's fun but not real hockey	1	4%		
didn't find much difference between 5.5 and 6, 6 is fine	1	4%		
I have not played a game yet	1	4%		
didn't like the 4.5 or 5.0, but 5.5 oz was fine	2	8%		
The 5.5 and 5.oz was O.K., I'm not sure, if I prefer it but I liked it			1	8%
Shoot harder, more accuracy			1	8%
You can shoot harder and have a better pass when off balance.			1	8%
I like the feel of the speed of the lighter shot but I could not say for sure I like the feel of stick handling.			1	8%
I need more time to play with the lighter puck, but I like it.			1	8%
Would like to try the puck for a longer period of time.			2	17%
Your technique or how much power you put into your shot can be less and you can still shoot				

hard.	1	8%
Shot with some ease.	1	8%
I think it will make the game quicker.	1	8%
I think I would like to try a lighter puck.	1	8%
Not sure, the 4.5 oz was too light	1	8%

3 Did it take a long time to adjust to the lighter pucks? Explain your answer.

responses	U22		NWT	
yes	13	52%	7	58%
no	9	36%	3	25%

reasons		
didn't have time to adjust, just carried out drills (4.5)	1	4%
adjusted a little bit too each one	1	4%
not much difference, 4.5 oz a little difficult to control	3	12%
a little	1	4%
lighter they are the less you have to do to get them up	1	4%
wasn't a huge difference	1	4%
depend on weight of puck	1	4%
wasn't too bad too adjust too, harder too adjust to passing	1	4%
much bouncier	2	8%
I kept shooting too high	1	4%
especially the lightest one	1	4%
5.5 oz O.K., others too light	1	4%
when you shoot they take off, go more quickly when you are		

passing	1	4%		
the very light pucks are a drastic change	1	4%		
2 or 3 shots of each puck	1	4%		
I think it would take some time.			2	17%
After the 4.5 oz had to adjust the angle of my stick so the puck wouldn't flutter			1	8%
I fel t like it was easier			2	17%
I never used it enough to answer this question.			2	17%
I just adjusted my follow through.			1	8%
Just the weight transfer.			1	8%
First few shots to adjust.			1	8%
I noticed more of a rebound than anything.			1	8%

4 Would you be willing to experiment with a lighter puck in a game? If no, why not?

responses	U22		NWT	
yes	20	80%	12	100%
no	3	12%		0%
reasons				
not a 4.5, maybe a 5.5 oz	3	12%		
I love hockey the way it is right now, why change	2	8%		
not the lightest one, it throws you off in speed of passes (hard to hang on to)				

5 The lighter pucks were easier to stick handle than the regulation puck.

responses	U22		NWT	
strongly disagree	3	12%		0%
disagree	7	28%		0%
slightly disagree	6	24%		0%
no difference	1	4%		0%
slightly agree	3	12%	4	33%
agree	2	8%	3	25%
strongly agree	2	8%		0%

reasons		
just different from normal, puck bouncing all over	1	4%

6 The lighter pucks could be shot with a greater velocity than the regulation puck.

responses	U22		NWT	
strongly disagree		0%	1	8%
disagree		0%		0%
slightly disagree		0%		0%
no difference		0%		0%
slightly agree	5	20%	3	25%
agree	10	40%	2	17%
strongly agree	9	36%	6	50%

7 The lighter pucks could be raised off the ice more easily than the regulation puck.

responses	U22	NWT

strongly disagree		0%		0%
disagree		0%	1	8%
slightly disagree		0%		0%
no difference	3	12%		0%
slightly agree	2	8%	1	8%
agree	7	28%	5	42%
strongly agree	12	48%	5	42%

8 Shots with the lighter puck were more accurate than the regulation puck.

responses	U22		NWT	
strongly disagree		0%		0%
disagree	4	16%	3	25%
slightly disagree	4	16%	3	25%
no difference	8	32%	1	8%
slightly agree	4	16%	1	8%
agree	1	4%	3	25%
strongly agree	3	12%	1	8%

9 The lighter pucks could be raised more easily than the regulation puck.

responses	U22		NWT	
strongly disagree		0%		0%
disagree	1	4%		0%
slightly disagree	1	4%		0%
no difference	2	8%		0%
slightly agree	9	36%	3	25%
agree	11	44%	4	33%
strongly agree			5	42%

10 The lighter pucks could be passed with a greater velocity than the regulation puck.

responses	U22		NWT	
strongly disagree		0%		0%

disagree	3	12%		0%
slightly disagree	4	16%		0%
no difference		0%		0%
slightly agree	4	16%	1	8%
agree	10	40%	1	8%
strongly agree	3	12%	3	25%

11 Passes with the lighter puck were more accurate than the regulation puck.

responses	U22		NWT
strongly disagree	3	12%	
disagree	8	32%	
slightly disagree	4	16%	
no difference	4	16%	N/A
slightly agree	5	20%	
agree			
strongly agree			

12 The lighter pucks could be received more easily than the heavier pucks.

responses	U22		NWT
strongly disagree	4	16%	
disagree	8	32%	
slightly disagree	6	24%	
no difference	2	8%	N/A
slightly agree	4	16%	
agree	1	4%	
strongly agree			

13 Breakaways were easier to perform with the lighter pucks compared to the heavier pucks.

responses	respondents	
strongly disagree		0%
disagree	3	12%

slightly disagree	3	12%	
no difference	6	24%	N/A
slightly agree	2	8%	
agree	1	4%	
strongly agree		0%	

14 Did you feel there was a difference in feel between the light weight pucks and the regulation puck. If yes, which of the light weight pucks do you feel made the greatest difference with respect to the feel of the puck while playing.

responses	U22		NWT	
yes	24	96%	11	92%
no				0%

responses				
4.5 oz	21	84%	8	67%
5.0 oz	2	8%	3	25%
5.5 oz	1	4%		

15 Do you think the lighter puck would enhance the development of shooting and passing skills in women's hockey? Explain your answer.

responses	U22		NWT	
yes	14	56%	11	92%
no	10	40%		0%
maybe/undecided			1	8%
reasons				
once it was used a bit more it would be great for younger, new players in the game	1	4%		
because you can be more accurate	1	4%		
don't have to be as strong, young				

girls would find it easier if brought in for younger kids the technique could be emphasized more, especially because they just want to raise the puck, now they could while practicing proper technique	1	4%		
but the lighter puck should be 5.5 oz, I didn't like the other ones	1	4%		
we won't be good with a regular puck after	1	4%		
the lighter pucks were fun but the regular pucks work great	1	4%		
you have to be strong to shoot the regular pucks	1	4%		
because it would be easier to work on technique	1	4%		
for young players, just as it would for young boys	1	4%		
we are adjusted to a weight	1	4%		
the lighter puck is hard to control	1	4%		
just because the puck is lighter doesn't mean you are a better passer	1	4%		
For the young players but after that they should use 6.0 oz.	1	4%		
At younger ages for both boys and girls the lighter puck would improve skill development.			1	8%
Yes, because in order for a female to get their shot off with speed, they have to have perfect balance and technique. A lot of times in a game, you are off				

balance and it is hard to be able to still shoot off of say one foot.			1	8%
Men are usually stonger than women, therefore a lighter puck would enhance our skills.			1	8%
We would shoot faster right away with and without hours of training.			1	8%
Overall, I think it would enhance the game, harder shots, more tape to tape passes.			1	8%
It also improves confidence and fun when you can succeed.			1	8%
Because it is lighter but we need more time to experiment with the pucks.			1	8%
Also the speed of the game.			1	8%
Possibly, but hard to say.			1	8%
Would allow greater control and accuracy, better execution.			1	8%

16 What do you feel would be the advantages of a lighter puck in women's hockey?

responses	U22		NWT	
faster game	8	32%	5	42%
faster shots	18	72%	9	75%
faster skating	2	8%	1	8%
faster passes	11	44%	9	75%
higher shots	9	36%	1	8%
faster goalies	4	16%	1	8%
easier to handle	2	8%	2	17%

17 What do you feel would be the disadvantages of a lighter puck in women's hockey?

responses	U22		NWT	
game too easy	2	8%		0%
shots too fast for goalies	2	8%		0%
shots too high for goalies	5	20%	1	8%
too, light difficult to handle	20	80%	8	67%
other:				
other:				
no disadvantage	1	4%		
puck may bounce too much			3	25%
4.5 oz not stable enough			1	8%
Too bouncy, the reflection off the				0%
boards makes puck flutter.			1	8%
Impact of viewers and how media				
etc., would portray its use.			1	8%

18 If you were to recommend a lighter puck, which would you prefer?

responses	U22		NWT	
4.5 oz			3	25%
5.0 oz	9	36%	6	50%
5.5 oz	16	64%	4	33%

19 How do you feel women's hockey would be viewed if lighter pucks were used? State any additional comments or concerns you may have on the use of a lighter puck in women's hockey.

responses	U22		NWT	
game too easy	4	16%		0%
game for a weaker sex	18	72%	3	25%
not real hockey	13	52%	2	17%
game is faster and more well				
played	2	8%	4	33%
enhances women's game	5	20%	7	58%
revolution of women's hockey			6	50%
other				

would hurt game, segregate us more from men's hockey, lose all the respect that we have gained	2	8%		
good for women's hockey			1	8%
I don't think the game would be viewed any differently.			1	8%
I think that at this time, we have gained the respect of many male viewers because we are paticipating as equals and are better than many of them.			1	8%
Depends on marketing.			1	8%

20 State any additional comments or concerns you may have on the use of a light weight puck in women's hockey.

responses	U22		NWT	
sacrifice puck control (initially)	1	4%		
shots would be harder	1	4%		
it's good, 4.5 is too light, bobbles a lot, 5.0 and 5.5 are good				
I like the idea.	1	4%		
not needed	1	4%		
4.5 oz very bouncy but would be very good for kids hockey	1	4%		
I think maybe slightly lighter would be fine, but I really am fine with the regular puck	1	4%		
The 4.5 oz is not a good weight. It makes receiving the pass too difficult since the puck tends to flutter and not stay on the ice	1	4%		
It is a good idea for younger players of both sexes but I feel the problem will arise with how people view women's hockey	1	4%		
I think the study is needed but am happy with the regular puck, thanks, it was fun	1	4%		
4.5 and 5.0 oz pretty hard to control, might recommend it for				

beginning or first year players.	1	4%		
That they are thrown into the game too quickly, people don't have time to adjust. The variety in physical sizes in women - what is too light for some is good for someone else - choose a standard and stick to it.			1	8%
During exercise I went from shooting 5.0 - 4.5 - 5.5 - 6.0. I found that switching 1/2 an ounce did not make a difference in speed/ technique but switching from 4.5 - 5.5 took both speed and technique away. But switching from 5.5 - 6.0 was fine. I think I really liked my first round which was 5.0. I think it will be great for our game!!! Relatively speaking how can you argue/make a negative remark, when men on average out weigh woman by about 50 or 60 lbs.			1	8%
I think the puck is a great idea, the only problem I can see is too bouncy.			1	8%
It is worth trying - however, should be used for a longer period of time for better measurement.			1	8%
It would improve the speed of the game and we would have more shots during the games. Maybe we could more people coming to and watching the game.			1	8%
I think women's hockey needs to have a lighter puck. The only thing holding women's hockey back in comparison to the men's game is the strength/speed of pass and velocity of shots. In shooting the different pucks against the boards, I found the blue and red to be extremely bouncy. The only one I found similar to the regulation puck in terms of handling was the yellow puck. It did not seem to be as bouncy as the others. I think this is a great idea and the lighter puck should be introduced in exhibition games and hopefully then used in the women's hockey game.			1	8%
It is good to use heavier weights to develop strength. I think it would have to be rated for different ages and skills.			1	8%
I think it is a great idea but we need more time using the pucks in different situations.			1	8%
The bounces off boards and the fluttering of puck when shot. I				

loved the 5.0 oz puck, it wasn't too light but a noticeable difference. The 5.5 oz was hard to notice a difference and the 4.5 oz puck was too light.	1	8%
Need to try in games and practices.	1	8%
I am not sure how I feel about it quite yet. I feel it would change the perceptionof the game. It might bring a negative view but other woman's sports have used it. It is worth try if it increases speed and accuracy of the shots on net and control of the puck.	1	8%