The performance of the ice hockey slap and wrist shots: the effects of stick construction and player skill

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Abstract

The purpose of this study was to examine the interaction of players' skill level, body strength, and sticks of various construction and stiffness on the performance of the slap and wrist shots in ice hockey. Twenty male and twenty female subjects were tested. Ten of each gender group were considered skilled and ten unskilled. In addition to general strength tests, each subject performed the slap and wrist shots with three stick shafts of different construction and stiffness. Shot mechanics were evaluated by simultaneously recording ground reaction forces from a force plate, stick movement and bending from high speed filming and peak puck velocity from a radar gun. Data were analysed with a 4-way repeated measures ANOVA for several dependent variables including peak puck velocity, peak Z (vertical) force, peak bending and stick to ground angles, peak angular deflection of the shaft, and hand placement on the stick. The results indicated that: 1) the slap shot was much faster than the wrist shot corresponding to greater vertical loading force, stick bending, and greater width of the hand placement; 2) the puck velocity was influenced by skill level and body strength but not stick type; and, 3) that skilled players were able to generate more vertical force and bend of the stick, in part, by adjusting their hand positions on the stick. Further studies are needed to address the specific influence of body strength and skill on the techniques of these shots and in relation to stick material and construction properties.

Keywords: deformation, ice hockey, shooting, stick stiffness, velocity

Introduction

In the last few decades, ice hockey equipment and the materials utilized have evolved substantially, including the hockey stick (Pearsall & Turcotte, 2000). The hockey stick is a fundamental implement for playing the game. Players use it for passing, stick handling, and shooting with different techniques. Two common shooting techniques of interest in this study are the slap and wrist shots. A slap shot is commonly used by both offensive and defensive players to generate maximum puck velocity. In general, the slap shot is executed by grasping the stick with both hands 0.40 to 0.60 m apart. In the slap shot, the stick is initially raised backwards then swung forwards with maximum effort to impact the puck upwards of 30 m/s or 100 km/h. The puck is propelled by the blade of the stick as shown in Figure 1 (Pearsall *et al.*, 1999). A wrist shot involves less swing than the slap shot and is used for higher accuracy, and the hands are held 0.15 to 0.30 m apart on the stick. Initially the stick blade

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begins in contact with the puck then the stick is swung forward in snapping or pushing action to propel the puck upwards of 20 m/s or 70 km/h as shown in Figure 2. The slap shot is a more powerful type of shot, but the wrist shot produces better shooting accuracy.

Several factors are commonly thought to influence the outcome of the shots such as skill level, body strength,

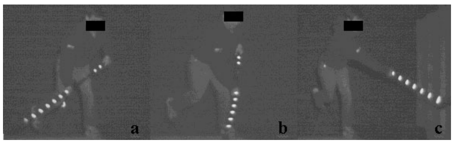

Figure 1 The phases of the slap shot include the backswing, downswing (a), pre-loading, loading (b), release and follow through (c).

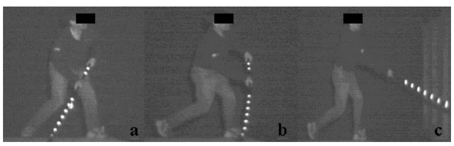

Figure 2 The phases of the wrist shot includes draw back (optional), blade positioning (a), loading, pushing (b), and follow through (c).

stick material type, and ice surface condition. More precisely, some of the mechanical factors identified as important in shooting specifically include: (1) the velocity of the lower (distal) end of the shaft prior to contact with the ice, (2) pre-loading of the stick, (3) elastic stiffness characteristics of the stick, and (4) contact time with the puck (Doré & Roy, 1976; Hoerner, 1989; Marino, 1998). However, the direct relationship between mechanical properties of the stick and shot performance has not been identified conclusively. This is an important issue to coaches and athletes alike. Recently to address this question, Pearsall *et al.* (1999) conducted a biomechanics analysis of slap shots performed by six highly skilled players using different sticks. Surprisingly, the stick stiffness properties had minimal effect on shot velocity for those players. However, given the small homogeneous sample, it is not possible to generalize to all player levels or all forms of stick shots. Hence, the purpose of this study was to investigate further the performance of the slap and wrist shots as affected by different stick types across different skill level and body strengths of the players.

Materials and methods

Data collection

Hockey sticks of carbon fibre composite, and wood laminate shaft construction with left- and right-handed blades were evaluated. The Bauer 300 (P66) blade of 0.0125 m curvature depth was used for all the sticks. The blade had a mass of 0.0025 kg. Each stick was coded so that the testers and subjects were unaware of the shaft brand during testing. The shafts were similar in length (0.140 m) and mass (0.320 kg). A difference among the sticks existed in deflection along the major axis, which is the common measure of shaft stiffness. The stick shafts were subjected to three point bending tests with 0.05 m linear deformation to measure shaft stiffness of the medium wood (13 ± kN/m), stiff wood (16.6 ± kN/m), and carbon composite (17.9 ± kN/m) shafts. These models are representative of the construction and range in stiffness readily available to hockey players.

Subjects

Forty subjects (twenty males and twenty females) completed the consent form and volunteered to participate in both the shooting and general strength tests of this study. Within each gender group, ten interuniversity or college level ice hockey players were classified as the skilled group; the remaining ten subjects with recreational experience in ice hockey were grouped as unskilled. Subjects were further selected to provide an equal distribution of right- and left-handed shooters, as well as to represent a range of body sizes and strengths. The players selected were 17 to 26 years of age (Table 1), and the skilled group was defined as participants in university or professional leagues (Junior A).

Testing apparatus

Similar test conditions were used to those in the prior study as shown in Figure 3 (Pearsall *et al.*, 1999). Data collection consisted of the simultaneous use of a force platform (AMTI OR6-5), a high speed video recording system (EG & G Reticon; San Diego, CA), and a radar gun (Sports Radar Gun Model SR 3300). The force plate was used to record the reaction forces occurring between the stick and surface during the shot. The puck was positioned to the front edge of the force platform to ensure that the stick struck the platform during the pre-

Table 1 General subject characteristics of the sub-groups

Gender\level	Skilled	SD	Unskilled	SD
Female				
Age (yrs)	19.1	1.7	23.0	4.7
Height (m)	1.66	0.06	1.63	0.07
Mass (kg)	66.5	6.5	58.8	7.9
Bench (kg)	43.7	5.1	37.8	6.7
Grip (kg)	40.3	3.5	33.5	3.9
Male				
Age (yrs)	22.8	1.6	25.4	7.3
Height (m)	1.78	0.08	1.72	0.09
Mass (kg)	83.0	5.8	77.3	6.6
Bench (kg)	93.0	22.1	82.0	26.7
Grip (kg)	59.0	11.6	57.5	9.1

loading phase of the slap shot. Lubricating fluid (WD-40 ™) was applied to the force platform to reduce the coefficient of friction between the force platform surface and the stick blade ($\mu_{static} \approx 0.5$). Data were recorded through virtual instrument software on an AT-MIO-16X (National Instruments ™) DAQ controlled by Labview ™ (Version 4.1) on a Pentium PC. Force-time profiles were recorded in the X (transverse), Y (front-back) and Z (vertical) directions.

To obtain the kinematics of the stick, a high speed video (480 Hz) was recorded during the shots. A camera was positioned 3.3 m laterally to the puck and 1.83 m vertically above the puck. The camera was oriented 20° below horizontal and approximately perpendicular to the stick's plane of motion determined from pre-trials. The reflective markers were placed on the stick shaft at 0.10 m intervals along the top 0.30 m and lower 0.60 m of the shaft. The markers were also placed on the back of the gloves over the left and right thumbs. The marker locations were digitized using the Ariel Performance Analysis System™ (Ariel Dynamics, San Diego, CA) and could be located to within 0.003 cm per pixel (picture element) from the video recording of a 1.5 m by 1.5 m field of view. Peak deflection (d), peak bending angle (q), attacking angle (b), and hand placement along the stick were the dependent stick variables obtained from this analysis (Figure 3). Peak deflection of simple bending observed in the camera's plane of view was calculated as the intercept angle (q) between projection lines from the upper and lower stick segments. The attacking angle (b) between the lower stick and ground surface was also calculated. The upper and lower stick segments were located between the top two and lowest two markers on the stick, respectively. A Sports Radar Gun (Model SR 3300) was used to record the peak velocity of the puck for each trial. The radar gun was located behind the target area of the hockey net. The peak velocity could be recorded between 1 and 65 ± 0.3 m/s, and the shots that were executed successfully into the target area were recorded as the official trials.

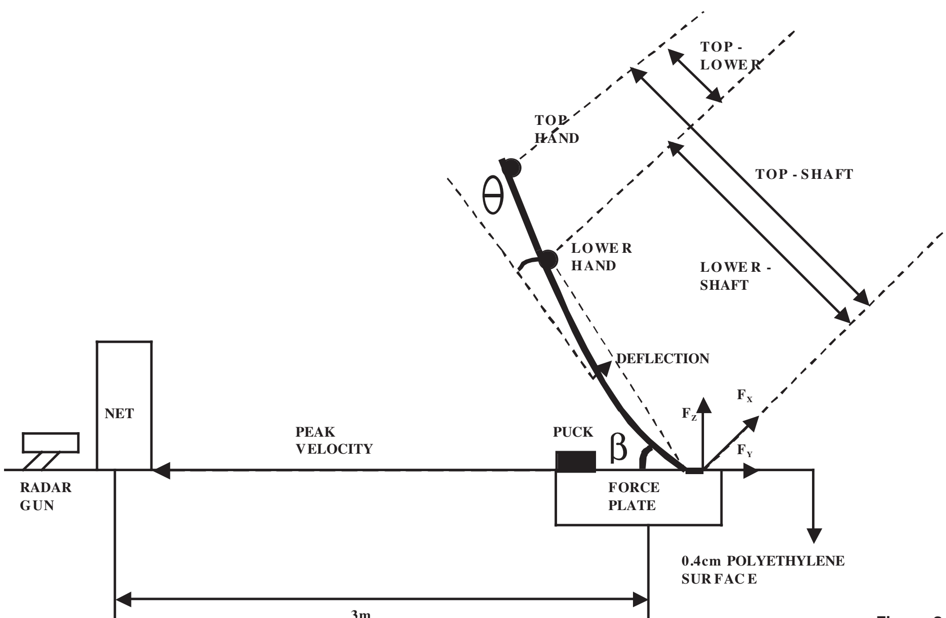

Figure 3 Set up of the experiment

Testing protocol

The subjects wore ice hockey skates and stood on a 3 m square piece of 0.004 m thick polyethylene (artificial ice) to execute the slap and wrist shots. Subjects performed a minimum of three practice trials with each stick. Each subject took three slap and three wrist shots with the various stick types in random order. A minimum of 30 s occurred between each trial of one stick type and a 3 min rest period occurred between sticks of different stiffness. A shot was considered a good trial if: (1) the puck went into the target area (0.60 m × 0.60 m) approximately 3 m from shot to goal, (2) the stick made initial contact with the force platform, and (3) the subject was satisfied that the trial was a maximal effort. Following the shooting test, the players also performed a general strength test consisting of 1RM bench press and a grip strength test. The subjects warmed up with a low resistance. After successful completion of one repetition, the weight was increased with a minimum of 2.2 kg increment, and the subject attempted the new weight after a brief rest. Each subject was given three chances to lift a maximal weight. Subsequently, all subjects performed a maximal grip test with a grip dynamometer. Each subject performed two grip tests with each hand, and the highest score for each hand was recorded.

Data analysis

The experimental design involved the subjects (S = 10) and the following independent variables: Gender (G = 2), Skill (Sk = 2), Shot type (Sh = 2), and Stiffness (St = 3), with repeated trials (T = 3). The data were analysed statistically using a repeated measure analysis of variance (ANOVA) for each dependent variable (Frank & Althoen, 1994). The dependent variables included puck velocity, peak Z (vertical) force, peak deflection, peak bending angle (q), stick to ground angle (b), hand placement on the stick. The ANOVA is described as S10(G2 × Sk2) × Sh2(St3 × T3). In addition, the relationship between strength test independent variables for Bench (B = 1) and Grip strength (Gr = 2) was compared with the above. All the data were measured and analysed by various software programs.

Table 2 Comparison of the stick mechanical measures for the slap and the wrist shots (e.g. lower hand – shaft = distance from lower hand placement to the end of the stick shaft)

Variables/shots	Slap mean	Wrist SD	Mean	SD	P
Velocity (m/s)	21.2	6.8	14.5	4.4	0.00
Vertical force (N)	97.6	63.6	44.2	30.0	0.00
Stick bending (degrees) q	12.7	5.5	10.8	5.6	0.03
Attacking angle (degrees) b	54.9	16.1	53.0	31.2	0.63
Lower hand - shaft (m)	0.593	0.093	0.626	0.039	0.07
Top hand - shaft (m)	1.193	0.100	0.959	0.049	0.00
Top hand - lower hand (m)	0.602	0.125	0.337	0.058	0.00
Shaft deflection (m)	0.038	0.016	0.032	0.017	0.03

Statistically significant different at $p < 0.05$, MANOVA 2W

Results

Slap shot versus wrist shot

In this experiment, all the players executed both the slap and wrist shots. On average, the slap shot produced greater peak velocities than the wrist shot, 21.2 ± 6.8 m/s and 14.5 ± 4.4 m/s respectively (Table 2). In general the slap shot had a peak vertical impact force of 97.6 ± 63.6 N, corresponding to an average shaft bending of 12.7° or 0.038 m. As for the wrist shot, the average peak vertical force was only 44.2 ± 30.0 N during the impact, corresponding to a peak bending of 10.8° and linear deflection of 0.032 m. Similar attacking angles (b) were seen in both the slap and wrist shots: 54.9° and 53.0° respectively. Significant differences between the slap and wrist shots were observed with respect to hand placements. In general, during the slap shot, the players would grasp their lower hand down the shaft from the shaft blade end (0.593 ± 0.093 m) than for the wrist shot (0.626 ± 0039 m). In contrast, the upper hand would be placed closer to the top (butt) of the stick (1.193 ± 0.100 m) for the slap than the wrist shot (0.959 ± 0.049 m). As a result, the distance between the upper and the lower hands was greater in slap (0.602 ± 0.125 m) than the wrist (0.337 ± 0.058 m) shot. No significant difference was found in the attacking angle (the angle between the stick and the floor) in both the slap and wrist shots.

Stick models, genders, and skill levels

With regards to various stick models, no significant differences in shot velocities were observed within either the skilled or unskilled groups. However, significant differences in peak velocity were observed between males and females, and skilled and unskilled sub-groups, among both the wrist and the slap shots (Table 3 and Figure 4). An observed covariate between the gender sub groups was body size and strength such that the male groups were stronger and taller in comparison to the female groups. Hence, body size and strength were presumed to be the primary factors in influencing the peak puck velocity, not gender per se.

On average, male skilled and unskilled groups performed the slap shots at 30.0 ± 2.6 m/s and 23.3 ± 3.9 m/s respectively and the wrist shots at 19.7 ± 2.8 m/s and 16.0 ± 2.5 m/s respectively. Female skilled and unskilled groups performed the slap shot at 18.8 ± 2.6 m/s and 13.3 ± 2.0 m/s respectively and the wrist shot at 13.6 ± 1.5 m/s and 9.4 ± 1.0 m/s respectively. In general, the slap shot was 1.2 to 1.4 times faster than the wrist shot.

In addition, the skilled players were able to shoot the puck faster and generated greater vertical force during the impact ($p < 0.05$). For the slap shots, the skilled players produced an average vertical force of 123.1 ± 68.0 N compared with 72.6 ± 47.6 N by the unskilled players as indicated in Table 4. For the wrist shots, the skilled players were able to generate 51.3 ± 38.0 N and 37.4 ± 17.3 N for the unskilled players as shown in Table 5. Corresponding to the greater vertical forces, the hockey sticks were bent to a greater extent during the slap shot. The stick shaft deflected 0.045 m for the skilled and 0.031 m for the unskilled players in the slap shot. In the wrist shot, the stick shaft also deflected 0.038 m and 0.027 m for the skilled and unskilled players respectively. A major difference in shooting technique between the skilled and unskilled players in the slap shot was the lower hand placement. The skilled players would grasp further down to the shaft of the stick with their lower (bottom) hand (0.551 ± 0.077 m) than the unskilled players (0.624 ± 0.094 m). In the wrist shot, the

Table 3 Average peak shot velocity for each type of sticks in each group

Male/Skilled				**Female/Skilled**			
Slap shot	**Velocity (m/s)**	**SD**	**CV**	**Slap shot**	**Velocity (m/s)**	**SD**	**CV**
Composite	30.6	2.6	8.5	Composite	18.4	2.8	15.2
Medium	29.2	2.6	8.9	Medium	18.7	2.8	15.0
Stiff	30.3	2.5	8.3	Stiff	19.2	2.1	10.9
Mean	30.0	2.6	8.6	Mean	18.8	2.6	13.7
Wrist shot				**Wrist shot**			
Composite	19.9	2.6	13.1	Composite	13.9	1.7	12.2
Medium	19.5	2.5	12.8	Medium	14.0	1.6	11.4
Stiff	19.6	3.1	15.8	Stiff	13.0	1.2	9.2
Mean	19.7	2.8	13.9	Mean	13.6	1.5	11.0
Male/Unskilled				**Female/Unskilled**			
Slap shot	**Velocity (m/s)**	**SD**	**CV**	**Slap shot**	**Velocity (m/s)**	**SD**	**CV**
Composite	23.0	3.8	16.5	Composite	12.4	1.9	15.3
Medium	23.3	3.6	15.5	Medium	14.0	2.4	17.1
Stiff	23.6	4.4	18.6	Stiff	13.4	1.7	12.7
Mean	23.3	3.9	16.9	Mean	13.3	2.0	15.1
Wrist shot				**Wrist shot**			
Composite	16.1	2.7	16.8	Composite	9.0	0.9	10.0
Medium	16.4	2.3	14.0	Medium	8.7	1.3	14.9
Stiff	15.5	2.4	15.5	Stiff	10.5	0.9	8.6
Mean	16.0	2.5	15.4	Mean	9.4	1.0	11.2

$p < 0.05$, ANOVA 4W analysis conducted

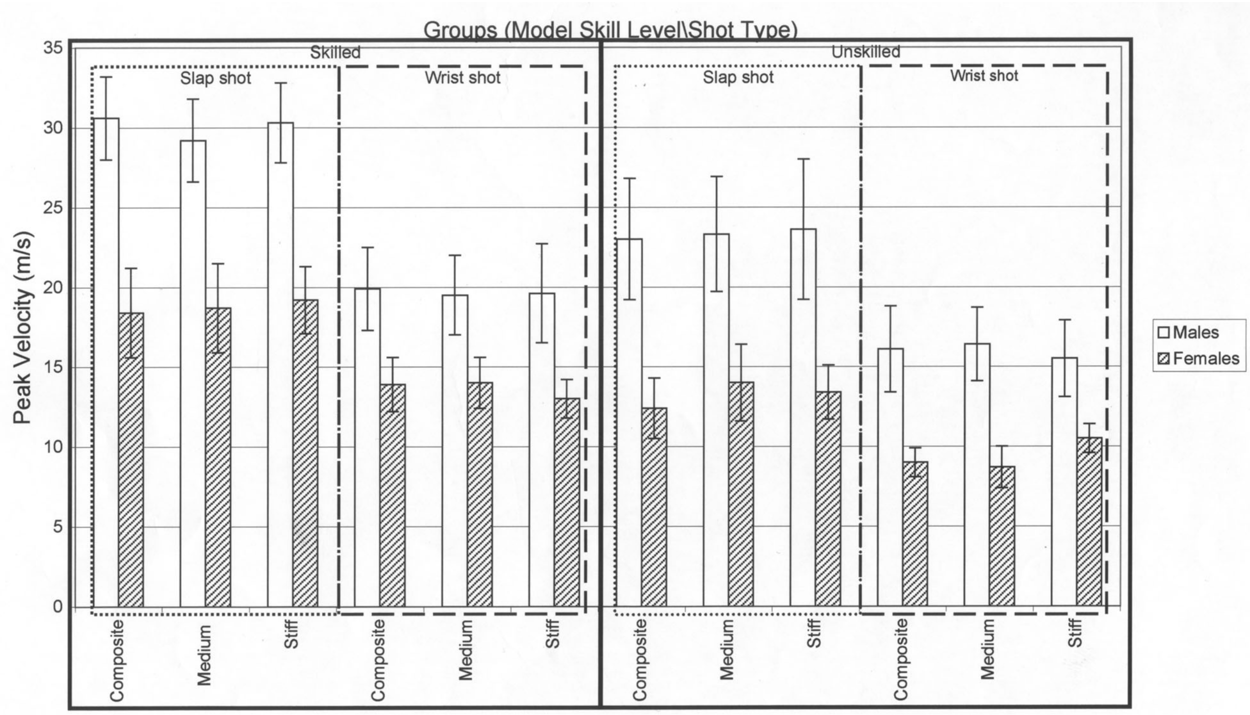

Figure 4 Comparison of the stick models (Composite, Medium & Stiff) in different skill level (Skilled & Unskilled), shot types (Slap shot & Wrist shot) and genders (Males & Females)

technique difference between the skilled and unskilled players was observed with the top hand placement. The skilled players would place their top hand lower (0.939 ± 0.040 m) than unskilled players (0.975 ± 0.050 m). In addition, it was observed that minimal differences existed in strength (bench and grip) and in the attacking angle between the skilled and unskilled players ($p < 0.05$).

Table 4 Comparison of the stick mechanical measures and upper body strength for skill levels in the slap shot

	Skilled		Unskilled		
Variables/Slap shot	Mean	SD	Mean	SD	P
Velocity (m/s)	24.3	6.2	18.3	5.9	0.00
Bench press (kg)	67.8	29.6	61.1	28.2	0.23
Right grip (kg)	49.5	12.6	47.1	14.4	0.34
Left grip (kg)	47.9	14.3	43.3	13.6	0.08
Vertical force (N)	123.1	68.0	72.6	47.6	0.00
Stick bending (degrees)	15.3	6.1	10.5	3.7	0.00
Attacking angle (degrees)	54.0	14.7	55.5	17.3	0.67
Lower hand – shaft (m)	0.551	0.077	0.624	0.094	0.02
Top hand – shaft (m)	1.187	0.062	1.197	0.123	0.78
Top hand – lower hand (m)	0.637	0.061	0.576	0.152	0.16
Shaft deflection (m)	0.045	0.018	0.031	0.011	0.00

Statistically significant different at $p < 0.05$, ANOVA 1W

Table 5 Comparison of the stick mechanical measures and upper body strength for skill levels in the wrist shot

	Skilled		Unskilled		
Variables/Wrist shot	Mean	SD	Mean	SD	P
Velocity (km/h)	16.6	3.7	12.4	4.1	0.00
Bench press (kg)	67.8	29.6	61.1	28.2	0.23
Right grip (kg)	49.5	12.6	47.1	14.4	0.34
Left grip (kg)	47.9	14.3	43.3	13.6	0.08
Vertical force (N)	51.3	38.0	37.4	17.3	0.01
Stick bending (degrees)	12.8	5.9	9.1	4.8	0.00
Attacking angle (degrees)	53.9	30.9	52.3	31.7	0.81
Lower hand – shaft (m)	0.624	0.031	0.627	0.046	0.81
Top hand – shaft (m)	0.939	0.040	0.975	0.050	0.03
Top hand – lower hand (m)	0.320	0.057	0.350	0.057	0.15
Shaft deflection (m)	0.038	0.017	0.027	0.014	0.00

Statistically significant different at $p < 0.05$, ANOVA 1W

Body size and strength

Within each sub-group, the peak puck velocity correlated most substantially to the subject characteristics in height, mass, bench press, and grip strength in both the slap and wrist shots (Table 6). Though it is not possible to establish a causal relation between these variables and puck velocity, it does suggest the importance of size and strength. In terms of stick properties, stick bending and deflection correlated highly to peak velocity (r = 0.80 to 0.90) in both the slap and wrist shots. In terms of technique, the slap shot was significantly correlated to lower hand placement and the distance between hands. The top hand placement and attacking angle were not significant. For the wrist shot, the attacking angle was the only technique variable that was significantly correlated to peak velocity (r = –0.39).

Table 6 Correlation between various variables in the slap and wrist shots with peak velocity

Variables/Shots	Slap shot	Wrist shot
Velocity	1.00	1.00
Height	0.64*	0.56*
Weight	0.88*	0.83*
Bench	0.79*	0.75*
GripR	0.67*	0.66*
GripL	0.59*	0.61*
Vertical force	0.91*	0.78*
Bending angle	0.80*	0.88*
Attacking angle	–0.06	–0.39*
Lower-shaft	–0.74*	0.09
Top-shaft	0.12	–0.34
Top-lower	0.61*	–0.34
Deflection	0.80*	0.88*

Discussion

In this study, the skilled and unskilled players performed the slap shot within a velocity range of 24.3 ± 6.2 m/s and 18.3 ± 5.9 m/s respectively. The results were in the range of the previous studies (Alexander *et al.*, 1963; Cotton, 1966; Chao *et al.*, 1973; Roy, 1974; Roy & Doré, 1976; Doré & Roy, 1976; Pearsall *et al.*, 1999 & 2001). For the wrist shot, the skilled and unskilled players performed at 16.6 ± 3.7 m/s and 12.4 ± 4.1 m/s. Roy & Doré (1974) had similar findings, but all other studies had reported higher velocity (Alexander *et al.*, 1963; Cotton, 1966; Chao *et al.*, 1973; Naud & Holt, 1975; Sim & Chao, 1978). The reason may be related to all the previous studies using elite male players only; hence, the shots were significantly faster for them. Similar differences were observed when comparing the stick bending angle with other studies. For the slap shot, this study recorded 15.3° ± 6.1° and 10.5° ± 3.7° for the skilled and unskilled players respectively. Previously, Pearsall *et al.* (1999) found the stick bending angle was 17.9° to 20.4° with six varsity players, and Naud & Holt (1975) reported the angle was 20° and 26° with two professional players. Both studies had small homogeneous groups so it was not possible to generalize to all the populations. In the wrist shot, this study found the stick bending angle to be on average 12.8° ± 5.9° and 9.1° ± 4.8° for the skilled and unskilled players, respectively. The only study that previously reported angles of 13° and 15° was with two professional players (Naud & Holt, 1975).

Not surprisingly, the slap shot produced greater puck velocities than the wrist shot. For the slap shot, the players tended to place their hands further apart on the stick than the wrist shot. This technique difference may, in part, allow greater vertical loading force and stick bending, resulting in the faster shots.

In addition, the results of this study suggest that the different stick stiffness properties did not significantly nor substantially affect puck velocity. Consequently, any two skilled or unskilled players can use any of the stick types and expect to produce the same or similar maximum velocity. When comparing stick models with the hand placement and attacking angle for the slap and wrist shots within the skilled and unskilled sub-group players, no significant technique difference was found. This indicates that the players did not change their hand placements or stick movement for the various stick models. It appears that the players' traits (i.e. skill, body and strength) were the critical factors in determining puck velocity in both the slap and wrist shots. This agrees with the previous study (Pearsall *et al.*, 1999). Moreover, vertical force, stick bending and deflection angles measures were observed; it should be noted that significant differences were observed between skilled and unskilled players, and no similar significant differences were observed in bench press, grip strength, peak attacking angle, and hand placement. Basically, the skilled and unskilled groups had similar physical strength characteristics, thus performance differences have to be attributed to technique difference. More specifically, when the skilled players were performing the slap or wrist shot, they struck the puck harder than the unskilled players as observed by the greater vertical loading force at the impact, and presumably this factor resulted in greater stick shaft bending and deflection. Other technique differences include hand positions: the skilled players would place their bottom hand lower in the slap shots and the unskilled players would place their top hand higher in the wrist shot. As an extension of the above, the player's height, weight, bench press, and grip strength variables were positively correlated to the velocity. Therefore, it may well be that in order to have a faster slap or wrist shot, both shooting technique (i.e. skill) and body strength are critical factors.

Several experimental limitations should be noted. First of all, the experiment was done in a laboratory on an artificial ice surface as opposed to an actual ice surface at the rink. Also, the subjects performed the task in a stationary position rather than with prior motion. These factors in mimicking the actual performance of playing conditions should be evaluated. Secondly, more accommodation time for the subjects to the testing conditions with each different stick type should be examined. For instance, though significant differences between sticks in shot velocity were not observed within the short duration of testing period, potentially the stick performance differences may change when a player learns or adapts to the advantage of different stick properties. Thirdly, the fixed stick length may also affect performance versus the player's preferred length of the stick. Players tend to cut the stick to a preferred height such that during a wrist shot the top hand is at the top (butt) end of the stick. Hence, a survey of players' height to stick length ratio should be conducted as well as a comparison of shot technique with their own stick to test sticks in order to identify the effect of stick length on shot technique in the future. Fourthly, in this study, the subjects ranged from 17 to 26 of age. Since it is not possible to extend the same findings for children and adolescents, further researches are needed within these age categories. Fifthly, this study did not examine interaction with other stick properties. For example, different blade stiffnesses and curvatures may affect shot performance (i.e. accuracy in the wrist shot and maximum velocity in the slap shot). For instance, Nazar (1971) reported a curved blade had better accuracy and velocity than straight blade hockey sticks. Lastly, this experiment was done on a 2D analysis in terms of technique. With more advanced technology and instrumentation, the 3D shot technique can be analysed. This way it will be possible to clearly identify the differences in shot technique between the skilled and unskilled players.

Some questions still remain unanswered from this study. For example, in this experiment the criteria for the performance were based on the peak velocity of the shot; however, other performance criteria such as accuracy of puck shot placement as well as the passing, receiving, and stick handling should be examined with respect to stick design. Moreover, in addition to general stick stiffness about the major axis, the axial torsion stiffness and the inhomogeneity of stick stiffness are other design variables of interest. Also, different hand placements and grip strength on the stick may cause the stick to bend and twist differently during the impact because of the different leverage effects on the shaft of the stick. Therefore, more in-depth studies are needed to address the importance of the physical characteristics and identify the specific motor technique of skilled shooting as well as the relation to stick properties.

Conclusion

This study was a continuation of a previous study done by Pearsall *et al.* in 1999. In this study, forty subjects of different skill levels and gender groups were used in both the slap and wrist shots. The peak velocity, vertical (Z) force and stick bending angle of each subgroup were identified in the two different types of shot. Also, in this research experiment, other important variables such as the different hand placements and stick attacking angle were incorporated in order to have a better understanding of relationships between the players and the hockey sticks during the impact. From the results, the researchers are able to evaluate the effects of stick construction and player skill more effectively and precisely.

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