**BIOMECHANICAL INVESTIGATIONS OF PERFORMANCE CHARACTERISTICS OF VARIOUS TYPES OF ICE HOCKEY STICKS**

**G. Wayne Marino,**
**University of Windsor and Louisville, Windsor, Ontario, Canada**

**KEY WORDS:** composite, wood, and aluminum shafts, statics

**INTRODUCTION:** The primary non-skating skills employed in ice hockey all involve use of a hockey stick to some degree. The importance of the stick is obvious in offensive skills such as shooting and passing. It is less obvious but equally important in defensive skills such as checking and face-offs. The selection and use of a stick depends on several factors which vary according to the level of hockey an individual is playing and on the skill level of the player. Cost, appearance, feel, performance, and durability are all areas that might be considered by various players. However, for those performing at elite levels feel and performance are likely the most significant factors. The stick must feel right in the hands before a player will consider using it and it must perform up to required standards in skills such as shooting and passing. The variables contributing to how a hockey stick feels and performs include primarily: weight, centre of mass location, shaft flex, resistance to twist, and breaking force. Together, these factors will determine the success of a manufacturer in promoting and selling a particular model.
At present, there are three primary types of ice hockey stick. The traditional stick is made of wood with a wooden blade being glued to a wooden shaft. Variants include fibreglass wraps that cover the blade or perhaps layers of laminated wood and fibre glass pressed into the shaft. A second type of stick incorporates a hollow aluminum tube (perhaps filled with foam to dampen vibrations) into which a wooden or composite blade is inserted at one end and a wooden plug at the other end. When the blade breaks it is replaced by another without the necessity of discarding the shaft. The third type of hockey stick is similar to the aluminum tube except that it consists of a hollow tube comprised of composite materials such as graphite and kevlar. These materials are combined with resins and fibreglass to form a shaft into which a blade and a plug are inserted. At amateur levels of play all types of sticks are in common use. At the professional level, aluminum sticks have been phased out over the past two years and with the rare exception all players use either wooden or composite graphite sticks. The differences between the three types of sticks that might contribute to performance and Afeel≅ have been a topic of concern for manufacturers of hockey sticks for the past several years. Baseline information on stick and shaft characteristics is important to future design and modifications of hockey sticks. Therefore, it was the purpose of this study to evaluate characteristics of various types of hockey stick shafts that contribute to the feel and performance capacity of the stick.
Professional hockey players and highly skilled amateurs select sticks intuitively on the basis of Afeel≅. In this study, large samples of wood (N = 40), aluminum (N = 32), and composite (N = 55) hockey sticks were evaluated for the following characteristics: weight, centre of mass, flex strength, torsional resistance, and breaking force. Although the sticks were sampled from several manufacturers, the test protocol followed a standard procedure used by Louisville Hockey to test for

performance characteristics and quality control.

**METHODS:** The independent variable in this study was type of stick. The three levels of the IV included: wood, aluminum, and composite ice hockey sticks. The dependent variables measured included: weight, centre of mass, flex strength, torsional resistance, and break force. No modifications were made to any of the sticks in the three samples. Thus, all sticks were assessed in their production or A off the shelf≅ form. It is to be expected that some of the characteristics of a stick will change somewhat when it is cut and tailored to fit the size requirements of an individual player. Weight was measured in grams through use of a Mettler-Tara top loading electronic balance. The centre of mass was determined by placing the stick on a vertical knife edge and shifting it=s location until the balance point was found. In each case the centre of mass was marked on the shaft with an indelible marker. Each stick was then stood against a graduated scale fixed to a vertical (plumb) support and the height of the centre of mass was determined. The location of the centre of mass was then calculated as a percentage of the standing height of the stick. The values represent a percent value with respect to the tip of the stick blade when the shaft of the stick is vertical with the toe of the blade resting on the ground. Shaft flex strength measurement represents a bending moment of the shaft and basically results in a value of force required to create a bend of 8.4 cm in the centre of the shaft. This force was measured using a prototype design 500 force transducer mounted in a wooden jig. The device emulates the hydraulic machine used to grade wood for shaft construction of Louisville wooden sticks. Torsional characteristics of the shaft are measured as the amount of twist that occurs along the long axis of the shaft when the shaft is subjected to a standard torque. A device was constructed using a metal base and a ball bearing fly wheel. At one end, the shaft of the stick was clamped tight and at the other end (1.14 m. away) a known torque was applied. This torque, which had a value of 5.87 N-m, caused the shaft to twist. The amount of twist was measured in degrees. Thus, a shaft with a high value indicated more twist than a shaft with lower values. Finally, the breaking force of each shaft was measured using a crank and pulley system which incorporated a force transducer designed to measure tension. Each shaft was clamped to a stainless steel table so that the break would occur at the edge of the table. A cable was fixed to the shaft at a standard distance away from the edge of the table and tension was put on the cable until the shaft broke. Since the force arm was constant and since the objective was between shaft comparisons only, it is legitimate to talk about the amount of force required to break the shaft rather than the amount of torque although in fact a torque was being applied.

Raw data were collected and collated for each of the three samples and then subjected to Independent Samples Analysis of Variance with unequal cell size. All comparisons were judged to be statistically significant at $P < .05$. Where warranted, further post-hoc multiple comparisons analysis was carried out to ascertain the precise location of statistically significant differences.

**RESULTS:**

Weight and centre of mass characteristics of the three samples of sticks are listed in Table 1. As can be seen, statistically significant differences occur in weight (F =

12.6). Post hoc comparisons indicated that wooden sticks are significantly heavier than either aluminum or composite graphite sticks. In addition, aluminum sticks are heavier than composite sticks.

**Table 1**

Weight and Centre of Mass of Wood, Aluminum and Composite Shafts

| Shaft | Weight (gms)* | C. of M (% of standing height) |
|---|---|---|
| Wooden (N = 40) | 691.5<br>(21.8) | 47.8<br>(1.1) |
| Aluminum (N = 32) | 633.2<br>(19.2) | 48.3<br>(1.3) |
| Composite (N = 55) | 604.8<br>(14.5) | 48.2<br>(.90) |

* Statistically significant differences between all three samples at $P < .05$

The results for flex strength and twist of each sample of shaft are indicated in Table 2.

**Table 2**

Flex Strength and Twist of Wood, Aluminum and Composite Shafts

| Shaft | Flex Strength (N) | Twist (degrees)* |
|---|---|---|
| Wooden (N = 40) | 625.8<br>(65.4) | 7.8<br>(2.1) |
| Aluminium (N = 32) | 668.2<br>(50.5) | 4.9<br>(1.1) |
| Composite (N = 55) | 659.3<br>(62.8) | 3.6<br>(1.6) |

* Statistically significant differences between all three samples at $P < .05$

As is evident, no statistically significant differences in flex strength was found between samples. This is to be expected as within sample variability is high. This fact is a result of intentional variation in the manufacturing process designed to produce sticks of various flex levels. A very strong player would choose an extra stiff shaft because it would produce the best storage of energy during shooting and, therefore, add to the velocity of the shot. A moderately strong player would select a stiff shaft for the same reason. It would bend a little easier than an extra stiff shaft and promote energy storage and release at an appropriate level. Finally, a weaker player would select a medium flex shaft because its bending and energy storage characteristics would again be appropriate for strength level. In summary, manufacturers produce sticks in all three materials that would fall into each of these categories.

A statistically significant difference was found in resistance to twist along the long axis of the stick ($F = 7.4$). It is apparent that wood shafts have least resistance to twist and aluminum have the greatest resistance. Composite shafts fall between but are closer to wood than aluminum. Since most players find that wood sticks are best for allowing the player to feel the puck when shooting and making and

receiving passes, it can be assumed that more twist (within limits) is desirable. Therefore, on this variable wood and composite sticks are better than aluminum.
The mean forces required to break the shafts of the sample sticks are listed in Table 3.

**Table 3**
Breaking Forces for Wooden, Aluminum and Composite Shafts

| Shaft | Break Force (N)* |
|---|---|
| Wood (N 0 40) | 430.3<br>(22.9) |
| Aluminium (N = 32) | 524.7<br>(17.4) |
| Composite (N = 55) | 426.3<br>(20.6) |

* Statistically significant differences between aluminum and other two shafts at P < .05

When break forces were evaluated it was found that statistically significant differences existed (F = 8.9). Further analysis indicated that aluminum shafts were stronger than either of the other types. There were no differences between wood and composites.

**SUMMARY AND CONCLUSIONS:** In summary it has been determined that composite sticks are lighter than those made with other materials. In addition, they are similar to other models in centre of mass location and flex strength. Wood sticks provide the best twist characteristics but composite sticks are a close second. Aluminum sticks are the strongest but they don't seem to allow a player to feel the puck as well. In addition, subjective evidence indicates that aluminum vibrates causing some difficulty with soreness in the hands. Since the precision level of composite manufacturing is better than wood technology, it can be concluded that composite sticks offer an attractive alternative to wood when weight, centre of mass, flex, twist, and strength are considered. The fact that most breakage in hockey sticks occurs at the blade and that in composite sticks the blade can be simply replaced further enhances the attractiveness of this type of hockey stick for both high level and amateur play. The on ice performance of these types of sticks especially those using new technologies in the manufacturing process has not been carried out. Further tests to assess the affect of the shaft on shot velocity and accuracy as well as passing and receiving effectiveness remain to be done.