IMPACT CHARACTERISTICS OF TWO TYPES OF HOCKEY ARENA BOARDS

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The purpose of this study was to investigate the energy absorption and energy transmission characteristics of two different types of ice hockey arena boards when impacted at both shoulder height and hip height. Traditional or standard boards were compared to a new, "softer", and theoretically more energy absorbent, type of boards. A pendulum system was designed to provide a method of impacting both the "glass" and "boards" sections with varying masses and at varying velocities. A Tri-axial accelerometer and a displacement transducer were attached to the pendulum mass to allow direct measurement of acceleration, velocity, and displacement during impact. Using these variables, forces and energies could be calculated. The results of this study indicated that standard arena boards returned 73 % more peak force per joule of initial energy than the new softer boards. The pooled data over conditions also indicated that the standard boards were 136 % stiffer than the new boards and that the new, softer boards absorbed 23 % more impact energy than their traditional counterparts. These results have particular relevance to the problem of injuries in the sport of ice hockey. It would appear that the softer boards are significantly better at absorbing impact energy and reducing peak forces, thus reducing the risk of injury on impact.

KEY WORDS: hockey arena boards, energy absorption, impact force, stiffness.

INTRODUCTION: In any collision the mechanical characteristics of the colliding bodies will determine the nature of energy absorption and energy transmission. In a perfectly elastic collision (in practice an impossibility) between a moving object and a stationary wall all of the pre-impact energy would be conserved and transmitted back into the body as it rebounded. If that moving body were the helmeted head or padded shoulder of a hockey player and the stationary wall was arena boards, the results of the collision could be catastrophic. At the highest professional level in ice hockey, for example, National Hockey League players suffered 70 cerebral concussions in the 1995-1996 season (Farber, 1996). Although some concussions are more serious than others, all result in some level of risk to the player. This ranges from brief posttraumatic amnesia with no loss of consciousness to lengthy loss of consciousness followed by severe headaches and long lasting amnesia (Cantu, 1992). Other types of injuries such as fractures, dislocations, abrasions and contusions can also result from high velocity impacts in hockey. In fact, research (Daly et al., 1990) shows that approximately 80 % of all ice hockey injuries occur as a direct result of trauma rather than overuse. Unless skating velocities and masses (which are the determining factors in pre-impact energy) are regulated, there are only two possible solutions to the problem of impact trauma. First, protective equipment must be designed to provide increased protection. Second, the playing environment must be made as safe as possible. It is this second area of concern that is the focus of this study. In the sport of ice hockey, the playing environment includes an enclosed ice surface. The enclosure consists of arena boards to a height of approximately 1.2 m topped by plate glass with metal partitions between glass panes (note: in some instances these metal partitions are absent and the glass is commonly referred to as "seamless"). The kinetic energy of a player, when colliding with the boards, is determined by a combination of mass and instantaneous velocity at the time of collision. In most cases, the total energy is concentrated over a relatively small area of impact such as the side of a helmet or the point of a shoulder or hip. The energy transmission and damping capability of the boards or glass will determine how much of that energy, if any, is returned to the impacting player and how much is dissipated or absorbed in movement of the boards and compression of protective equipment. The real challenge is to reduce the amount of energy returned to the player. In addition, the actual force of impact is also of concern. The peak force is an indication of how energy absorbent the boards and glass are. Since the amount of work done against the boards is a direct result of the impact kinetic energy, the effectiveness of the boards is reflected in lower peak forces. If the distance traveled by the impacting body increases during collision, the average force will decrease. Therefore, in softer boards and glass, both the peak forces and the amount of energy transmitted back to the colliding player should be lower. This would in turn make the playing environment safer for players. The purpose of this study, therefore, was to compare the energy absorption characteristics of traditional or standard arena boards and glass to those of new, "softer" arena boards and glass.

METHODS: In order to create impacts of the necessary magnitude, a pendulum system was developed consisting of a weighted bar supported by adjustable cables. The impact surface was covered with protective padding and a hard shell to emulate the impact area of a hockey helmet or pad. A Tri-axial accelerometer was secured to the bar just behind the impact surface. A displacement transducer cable was attached to the distal end of the pendulum and the transducer was attached to an immovable tripod. When combined with the mass of the pendulum system, forces and energies during impact with the arena boards could be calculated. Two impact heights were selected for testing. The first, 90 cm, reflected the 50^{th} percentile for the height of an adult male hip, and, the second, 140 cm, reflected the 50^{th} percentile for the shoulder. Actual testing consisted of pulling the pendulum back away from the boards and letting it swing freely until impact. Thus, gravity acting on the mass of the pendulum created the energy observed at impact. In the higher speed trials, the pendulum was pushed to give it an initial velocity before gravity took over. A large number of trials was conducted under each condition to ensure a wide range of data. In all, 170 impacts were made against the softer boards and 142 against the standard boards. There were four independent variables in this study: type of arena boards tested, impact height, pendulum mass, and pendulum velocity. The dependent variables were a series of measures reflecting the impact characteristics and energy absorbing capacity of the boards and glass. The main variables used for comparative purposes were: peak force at impact, board stiffness (peak force/displacement), and energy absorption (% of impact energy absorbed). Accuracy and validity of the measurement system was verified by comparing the kinetic energy stored in the pendulum at impact to the amount of work done by the boards or glass to arrest its forward motion.

RESULTS: In comparing the energy of the bar at impact and the work done by the boards, it was determined that for both types of boards the relationship between work and energy was linear with the slope of the line of best fit being very close to 1.0. In addition, the R^2 values were .986 and .986 for the two sets of boards respectively. These results indicate that the test protocol was valid and produced reliable results across the whole energy range used in the study. During impact, the boards will exert an equal and opposite force on the impacting body. The values for peak force slope, which compares peak force to the known energy of impact, were pooled across conditions and are presented in Table 1. It is apparent that, when pooled over all combinations, Standard boards produce an average of 73 % more peak force per joule of initial energy than the new "softer" boards. Stiffness of the boards is a measure of how much force is required to move the boards through a given displacement during impact. Stiffer boards are harder to displace and, therefore, would return more energy to the impacting body. The peak stiffness slope (increase in stiffness per joule of kinetic energy on contact) values pooled across all conditions are listed in Table 2. The pooled data indicate that on average, standard boards are 136 % stiffer than the new "softer" type boards tested in this project. The ultimate test of hockey arena boards is the ability to absorb energy when a body or body part impacts either the board or glass section. The more energy that is absorbed by the boards the less will be returned to the player. Less energy returned to the player will ultimately reduce the risk of traumatic injury. The energy absorption data were separated into two pools to reflect impact at both hip height and shoulder height. The data for this variable are listed in Table 3. Both standard boards and "soft" boards absorbed approximately the same percent of the impact energy at hip height and there were no statistically significant between condition differences at that height. At shoulder height, the standard boards absorbed only 76.1 % of the impact energy while the "soft" boards absorbed 93.8 %. Therefore, the softer boards absorbed 23 % more energy than standard boards at the shoulder height. It is probable, therefore, that the new boards create a lower risk of serious injury than the standard boards.

Table 1. Peak Force Slope For Each Condition Tested and Pooled Across Conditions.

Peak Force Slope (N/J)	Soft Boards		Standard Boards		% Increase from Soft to Standard Boards	
Height	Hip (90cm)	Shoulder (140 cm)	Hip (90 cm)	Shoulder (140 cm)	Hip (90 cm)	Shoulder (140 cm)
Weight						
60 kg	81.4	127.1	234.2	144.2	188 %	13 %
82 kg	129.6	135.1	195.6	146.5	51 %	8 %
Both Loads	106.1	132.6	201.6	145.2	90 %	9 %
All Conditions	**112.8**		**195.7**		**73 %**	

Table 2. Peak Stiffness Slope For Each Condition Tested and Pooled Across Conditions.

Peak Stiffness Slope (N/cm/J)	Soft Boards		Standard Boards		% Increase from Soft to Standard Boards	
Height	Hip (90cm)	Shoulder (140 cm)	Hip (90 cm)	Shoulder (140 cm)	Hip (90 cm)	Shoulder (140 cm)
Weight						
60 kg	24.5	51.7	127.3	74.2	420 %	44 %
82 kg	56.0	48.5	78.2	89.8	40 %	85 %
Both Loads	37.9	54.7	95.6	76.1	152 %	39 %
All Conditions	**39.5**		**93.4**		**136 %**	

Table 3. Percent of Impact Energy Absorbed at Two Different Heights.

Type of Boards	Hip Height	Shoulder Height
Soft	76.4 %	93.8 %
Standard	74.7 %	76.1 %

CONCLUSIONS: The purpose of this study was to compare the energy absorption characteristics of a new type of "softer" arena boards and glass with those of standard or traditional boards and glass. A pendulum system of known mass (60 kg and 82 kg were the two masses used) was constructed adjacent to both types of boards and was fitted with electronic displacement and acceleration measurement devices. The pendulum was swung at two different heights (90 cm and 140 cm) and at a wide range of velocities to test the stiffness and energy absorption characteristics of both types of boards. Tests were also completed to determine the validity of the measurement system. Results revealed that the measurement system did provide accurate, valid results at both masses and both heights across the whole range of velocities tested for both types of boards. Analysis of stiffness and energy absorption qualities indicated very favorable results for the new "softer" boards in comparison to standard boards. Overall, standard boards were found to be 136 % stiffer than the "soft" boards and to produce, on average, peak forces 73 % higher. In addition, the "softer" boards were found to absorb 23 % more energy at shoulder height. This would appear to have particular relevance to the problem of injury in ice hockey. Since many impacts occur between player's shoulders and/or helmets and the glass, it is necessary for the glass to absorb significant amounts of energy to help prevent injury. It would appear from analysis of the data in this study that the newer "soft" boards are significantly better at absorbing impact energy and reducing peak forces, thus reducing the risk of injury on impact.

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