BIOMECHANICS OF THE PENALTY STROKE IN ROLLER HOCKEY

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This paper describes a preliminary study on the biomechanics of the shot in roller hockey. This is a Portuguese sport having a most extensive prize list, where Portugal has been 15 times world champion, 20 European champions in senior male competition and won three world championships in senior female. Despite this impressive collection of titles, hockey continues to be the lesser studied sport, concretely regarding studies on biomechanics. The influence of sports equipment in the athlete's performance and a detailed analysis of the main technical gestures had not motivated yet the researchers for detailed studies to enable their optimization. The purpose of this study was to characterize the mechanical properties of the stick (Aleu) and its influence on the shot power.

KEY WORDS: biomechanics, penalty stroke, roller hockey.

INTRODUCTION: The roller skate hockey is a team game where athletes run on wheels, which require high level of motor coordination. In roller (or rink) hockey the floor contact is materialized by eight supporting points having defined values of friction and rolling contact factors of the wheel/floor pair. Such constraints severely limit some of the athletes' movements, this imposing alternative training and skill in terms of balance and handling in the player's attitude. Also the interaction between the player and the ball is equivalent to a system of multi-body dynamics.
The shot is a muscular power movement demanding a great commitment to improve this motor action. During this movement a huge amount of muscle energy is generated in a short time interval, while the athlete tries to stand in perfect balance just on one foot. This action can be dynamically modelled in the scope of Applied Mechanics with the theorem of momentum, where the impulse on the ball during the shot represents the quantity of motion by the athlete´s body. It should be noted that the speed of the ball weighting some 0.144 kg topped by a senior athlete easily reaches 100km/h. In opposition to ice hockey the stick is never used as a spring like in the slap shot.

METHODS: In this work were involved 15 athletes from different positions and levels from 1st (7) and 2nd (8) Portuguese league, with the mean age of 24 ± 6 years old, 1.75 m ± 0.05 m of height and weighting 75 kg ± 8 kg, free for history of muscle injury. A high speed video camera Photron Fastcam SA 2, placed in a tripod in the sagittal plane and sampling at 1000 Hz was used to record the shooting trials performed by the athletes. This high sample rate was used to accurately visualize the deformation of the stick during the interaction with the ball and estimate the corresponding bending angle and contact time during the hit. A Stalker ATS radar (33.4 to 36 GHz) was placed behind the goal, in the frontal plane to the athlete, to collect the ball velocity data. Each athlete comprises 3 shot trials.
To better understand the stick behavior a numerical simulation of the stick/ball interaction, considered the stick as the deformable element, while the ball is assumed as perfectly rigid, was performed with Pseudo dynamic techniques. This study where used to simulate the mentioned stick-ball interaction during the energy transfer between the athlete and the ball. Alongside some experimental devices were constructed to assess the main characteristic parameters of the stick that influence the shot, *i. e.*, weight, C.G. position and weight in balance. It should be noted that each athlete tries to adapt the stick to their physical

characteristics and function in the game. With the equipment designed and built in LOME - INEGI it was possible to completely characterize each of the stick samples and understand the options for each athlete. Figure 1 show the experimental layout designed to analyze the mass balance.

Figure 1: Evaluation of mass balance of a stick.

An experimental complementary analysis was also carried out to characterize the kinematics of the athlete motion during the performance of this technical gesture. For this preliminary study one athlete of the group was selected to participate on measurement program at the Laboratory of Movement Analysis - MovLab *Universidade Lusófona de Humanidades e Tecnologias* of Lisbon. A twelve VICON cameras setup synchronized with a force platform, AMTI-BP400600, were used to record the cinematic and kinetic data. The aim of this measurement was to identify the exact time instant when stick comes to the contact with the ball.

RESULTS: The table 1 shows the results obtained for the ball speed measurement in two different situations, with and without a short approach run for all the athletes.

Table 1
Terminal Ball speed

	Ball speed (km/h)	
	Mean	SD
No approach run		
2nd league (8)	90.3	5.2
1st league (7)	102.0	4.6
With approach run		
1st league (7)	115.4	7.2

Figure 2 shows the different ways the athlete perform a penalty shot with a still ball. As can be seen the stick bends during the contact with the ball. The angle of bending measured was 18.5º (± 3.2º).

Figure 2: Penalty shot during the beginning of contact stick/ball

The athlete selected for the cinemetry measurements performed 17 penalty shots in the MovLab. In all the trials the ball speed and vertical force history were also recorded. In figure

3 is presented an image recorded during 7nd trial and a graphic presentation of the right hand acceleration during the shot execution. This graphic, was obtained with data collected during the 7th trial and clearly shows that the athlete hits the ball when his harm is not at maximum acceleration.

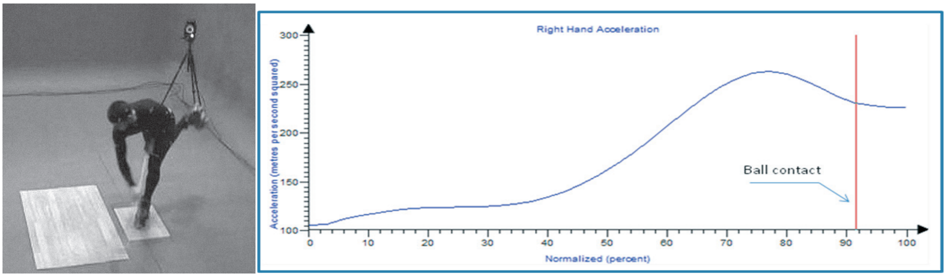

Figure 3: Cinemetry measurements at MovLab and normalized record of right hand acceleration.

DISCUSSION: This work shows that these techniques are well adjusted to the objectives defined for this study. The assessment of the ball speed allows the control of the shot power for each athlete. The high speed video recording could be used to obtain the stick deformation during the gesture. The maximum deformation amplitude was imposed in a three point bending test to a stick instrumented with a strain gage and a load close to 80 N was measured. Using the equipment developed the stick can be fully characterized to investigate its influence in the shot kinetics. This way it will be possible to obtain a good estimation of the energy transferred to the ball by measuring the force, velocity and contact stick/ball duration, being the last the most difficult to evaluate. However, it was detected that the contact time stick/ball varies according to the way the athlete performs the shot, being some strategies more efficient than others. So, it will be also important to characterize in detail the strategy of muscle activation that promotes each athlete and record the effects and efficiency gains from their act. Same methodology should be followed to understand the contribution of the stick in the improvement of the shot and how their mechanical properties and mass distribution may be adjusted the characteristics of each athlete.

CONCLUSION: From the work performed it can be concluded that the experimental equipment allows an accurate characterization of the dynamic behaviour of the sticks. The study of the stick movement when striking the ball confirmed the importance of a good technique for efficient energy transmission to the ball. Kinematic analysis of the movement of each athlete allowed the evaluation of the ball/stick contact time, having also correlated the registered values with the terminal velocity of the ball. Future research will draw an additional study with electromyography to enable better understanding of the biomechanics of this movement and the strategy used by each athlete to obtain maximum performance. The movement of the stick should be defined considering its mechanical properties to promote a longer contact with the ball. This way a maximum energy transfer to the ball will be achieved.
The continuity of this work should help develop new training methods to improve the shot and develop techniques that allow building sticks suitable for biomechanical characteristics of each athlete.

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