Using 3D Motion Capture to Analyse Ice Hockey Shooting Technique on Ice

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Abstract: This study investigates the feasibility to use a passive marker motion capture system on ice to collect 3D kinematics of slap shots and one timers. Kinematic data were collected within a volume of 40x15x2 m by 20 motion capture cameras at 300 Hz, a resolution of 12 megapixels and a mean residual for all cameras of 3.4±2.5 mm, at a distance of 11.6 m. Puck velocity, blade velocity, ice contact time and distance to the puck were analysed for ten consecutive shots for each technique, for two professional ice hockey players. The total mean puck velocity was 38.0 ± 2.7 m/s vs. 36.4 ± 1.0 m/s. (p=0.053), for one timers and slap shots respectively. One player had higher puck velocity with one timers compared to slap shots 40.5 ± 1.0 m/s vs. 36.9 ± 1.0 m/s (p=0.001). Puck contact time was longer for slap shots than for one timers, 0.020 ± 0.002 s vs. 0.015 ± 0.002 s, (p<0.001). The motion capture system allowed continuous kinematic analyses of the puck and blade velocities, ice contact times and detailed stance information. The results demonstrate the possibilities to use motion capture systems to collect and analyse shooting kinematics on ice, in detail.

1 INTRODUCTION

Ice hockey is a physical demanding sport with high intensity and tempo that obliges the players to have excellent physical condition and high levels of precision and technical skills. The shooting technique is an essential keystone in ice hockey and the two most commonly used shooting techniques in ice hockey are the slap and the wrist shots. The slap shot generates the highest puck velocities (33 - 36 m/s), whereas wrist shots generate lower puck velocities (20 - 28 m/s) but generally with higher accuracy compared to slap shots (Michaud-Paquette, Magee, Pearsall, & Turcotte, 2011; Villasenor, Turcotte, & Pearsall, 2006; Worobets, Fairbairn, & Stefanyshyn, 2006).

The slap shot is generally divided into six different phases: i) the backswing, ii) downswing, iii) preloading, iv) loading, v) release and vi) the follow through (B. Kays & Smith, 2014; Pearsall, Montgomery, Rothsching, & Turcotte, 1999). During preloading, the stick contacts the ice several inches behind the puck to initiate the bending of the stick. The puck is then impacted during the loading phase, which increases the bending of the stick. The built-up strain energy in the stick is then transferred to the puck during the release phase.

A wrist shot uses less swing compared to a slap shot and the player starts with the puck near the heel of the blade. The puck is propelled forward as the player does a forward sweeping motion while creating shaft bending by applying a downward pressure. The puck then rolls of the blade as the shaft recoils (B. Kays & Smith, 2014; Pearsall et al., 1999).

Several studies have used high speed video or motion capture to investigate these two different shooting techniques as well as how the stick stiffness affects the puck velocity (Frayne, Dean, & Jenkyn, 2015; Goktepe, Ozfidan, Karabork, & Korkusuz, 2010; Hannon, Michaud-Paquette, Pearsall, & Turcotte, 2011; Michaud-Paquette et al., 2011; Pearsall et al., 1999; Villasenor et al., 2006). However, to the authors knowledge there are no studies investigating a third shooting technique, the “one timer”, which is similar to a slap shot but with the difference that the player meets the puck with an immediate slap shot, without touching or trying to

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control the puck first. The one timer is a shooting technique that often initiates a rapid change of direction of the opposing defenders and is frequently used in power plays where at least one opposing player is serving a penalty.

Previous ice hockey studies on ice, have mostly used high speed cameras to capture kinematic data while studies using 3D motion capture systems have been executed off-ice by simulating real ice condition by using e.g. synthetic ice (Frayne et al., 2015; Goktepe et al., 2010; B. T. Kays & Smith, 2017; Michaud-Paquette et al., 2011; Worobets et al., 2006).

Stidwall et al. (2010) investigated skating kinetics and kinematics on ice and on synthetic ice and found that synthetic ice permits comparable mechanics for on-ice forward skating. However, it is fair to assume that the large difference in friction coefficients between ice and synthetic ice (μ = 0.003 to 0.007 vs. μ = 0.27) can affect the mechanics in technical exercise such as shooting and agility drills. It can also be hypothesised that shooting kinematics, stance and distance to the puck at impact differ between slap shots and one timers as one timers depends greatly on timing and how the player positioning himself in relation to the incoming puck, to achieve a good shooting technique. Hence, there is need for a 3D kinematic system that can be used on ice to acquire realistic, detailed and accurate ice hockey shooting analyses.

Upjohn et al. (2008) stated that passive marker systems for motion capture have limited applications for collecting data in a field setting due to the large capturing volume needed for ice hockey and problems with controlling ambient lighting. However, new and better motion capture systems have developed during the last years which allow data capturing in poor lighting conditions, e.g. outside in sunlight and/or in vast capturing volumes with large quantities of unfavourable reflections. Shell et al. (2017) and Renaud et al. (2017) used modern motion capture systems to analyse ice hockey skate starts on ice. Still, the use of a marker-based motion capture system to collect 3D kinematics of different ice hockey shooting techniques on ice has yet to be tested.

The main purpose of the current study was to investigate the feasibility to use a passive marker motion capture system to collect 3D kinematics of professional ice hockey players on ice while performing shooting exercises. A secondary aim was to investigate possible differences between the conventional slap shot and the one timer shot with regard to puck velocity, blade velocity and distance to the puck at puck contact.

2 METHOD

Two professional ice hockey players were recruited (player A and B) from a team in the Deutsche Eishockey Liga (DEL) in Germany. Both players were right hand shooters and used their own skates, gloves, helmets and sticks. Soft reflective markers were attached to the skates at the front tip, the heel and at the position of the lateral malleolus. Six markers were placed on each stick where four markers were placed on the shaft, 0.30, 0.57, 1.1 and 1.5 m below the top of the shaft and two markers were place on the heel and the tip at the backside of the blade. For velocity measurements, markers were placed on every puck. Each marker had a diameter of 15 mm and was attached by double-sided tape and additionally fixed with tape around the base to avoid movement of the markers.

The players performed a 15 min individual warm up, including the various shooting techniques. Following the warm up, to familiarise themselves with the test setup, both players completed 20 shots. During the data collection, each player performed 10 slap shots and 10 one timers, in opposite order. With the one timers, the puck was hit directly from a pass, coming from a 45 degrees angle to the right. All 10 shots in each series were executed in one sequence without any rest between each shoot. For the slapshots, all 10 pucks where lined up next to each other and with the one timers, the next puck was passed directly after the previous shot. The players had a five minutes rest between the two different shooting techniques.

Data were collected within a volume of 40 x 15 x 2 m by 20 Qualisys Uqus 7+ cameras (Qualisys AB, Gothenburg, Sweden) at 300 Hz and with a resolution of 12 mega pixels. Eight cameras were positioned on high tripods, placed on isolated plates on the ice to prevent the tripods from melting down into the ice. The remaining 12 cameras were placed on top of the safety glass surrounding the rink (Figure 1).

Protective padding was positioned behind the goal to collect the pucks and to protect the boards and glass from being hit by a puck and hence cause camera movements. The measurement volume was calibrated by using a hand-held T-wand, consisting of two reflective markers at each end, with a known distance between them. The orientation of the coordinate system was performed by placing an L-frame at the

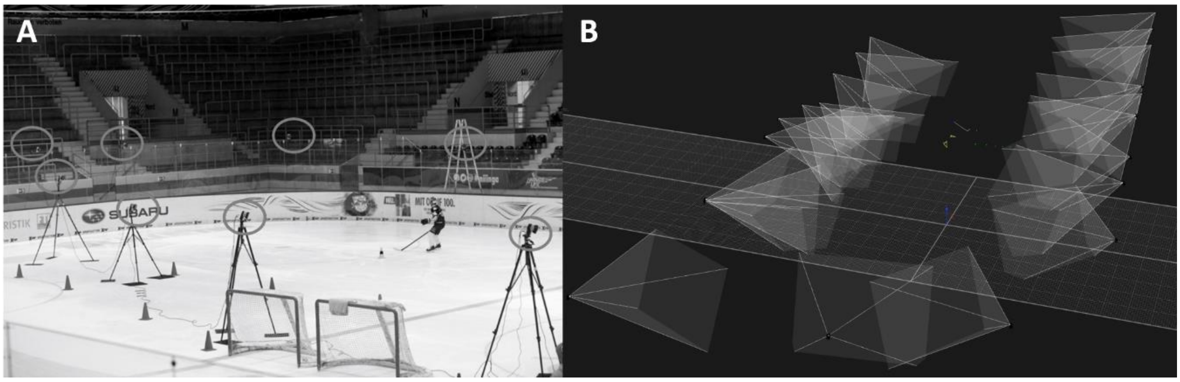

Figure 1 A: Overview of half of the capture volume where the cameras are highlighted with circles. Photo courtesy of Reimund Trost, Qualisys AB. B: 3D view of the capture volume where the player's stick, markers on the skates and pucks are visible.

decided origin. The mean residual for all cameras was 3.4 mm, s = 2.5 mm, at a distance of 11.6 m from each camera.

2.1 Data Analysis

Stick blade velocity was determined by the resulting speed of the marker, positioned at the tip of the blade. The velocity data for all shots in each session were synchronised concerning the time of puck contact. The puck contact time was determined from the 3D kinematic data.

Shooting stance was calculated as the distance, d, between the left and right lateral malleolus markers, in the xy-plane (the transverse plane) by equation 1.

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \tag{1}$$

where x_1, y_1, x_2 and y_2 are the xy-coordinates for the left and right ankle markers respectively.

The distance from the player to the puck was defined as the shortest distance between the puck marker and the line between the left and right ankle markers in the xy-plane. The line was constructed by using the basic slope-intercept equation for a straight line through two points, Eq. 2 and Eq. 3.

$$y - y_1 = m(x - x_1) \tag{2}$$

where m is calculated by:

$$m = \frac{y_2 - y_1}{x_2 - x_2} \tag{3}$$

The general form of a linear equation is:

$$ax + by + c = 0 \tag{4}$$

and the distance D from a point P_0 (x_0,y_0) to this line can be calculated by Eq. 5.

$$D = \frac{|ax_0 + by_0 + c|}{\sqrt{a^2 + b^2}} \tag{5}$$

The data analyses from the two players and for each condition were averaged separately for each player. All data were checked for normality, calculated with conventional procedures and presented as means ($\bar{x}$) and standard deviations (± SD). The coefficient of variance was calculated as:

$$CV = \frac{SD}{\bar{x}} \tag{6}$$

and presented in percent.

Significant effects between shooting techniques were investigated with a two-sided paired Student t-test and a unpaired two-sided Student t-test between players, choosing an alpha level of 0.05 as criterion for significance. Hedge's g effect size (ES) was further calculated and ranked as low (0.2), medium (0.5) and high (0.8+) (Thomas, Salazar, & Landers, 1991) to determine the meaningfulness of the differences between one timers and slap shots between and within the same player.

3 RESULTS

Mean maximal puck velocity for slap shots versus one timers for player A and B, respectively, were 36.0 ± 0.9 m/s vs. 35.4 ± 1.0 m/s (p = 0.4, ES = 0.54) and 36.9 ± 1.0 m/s vs. 40.5 ± 1.0 m/s (p = 0.001, ES = 3.2). The total mean puck velocity showed a trend towards lower velocity for slap shots compared to one timers 36.4 ± 1.0 m/s vs. 38.0 ± 2.7 m/s, (p = 0.053, ES = 0.79). Both players had a lower coefficient of variation when shooting slap shots compared to one timers 9% and 7% vs.14% and 34%.

The blade velocities for slap shots and one timers can be seen in Figure 2 A-B and the puck contact time for slap shots was significantly longer compared to one timers, 0.020 ± 0.002 s vs. 0.015 ± 0.002 s, ($p < 0.001$, ES = 2.2).

The perpendicular mean distance to the puck at impact for slap shots versus one timers for player A and B respectively, was 0.95 ± 0.05 m vs. 0.86 ± 0.08 m ($p = 0.07$, ES = 1.2) and 0.97 ± 0.09 m vs. 0.95 ± 0.07 m ($p = 0.4$, ES = 0.2).

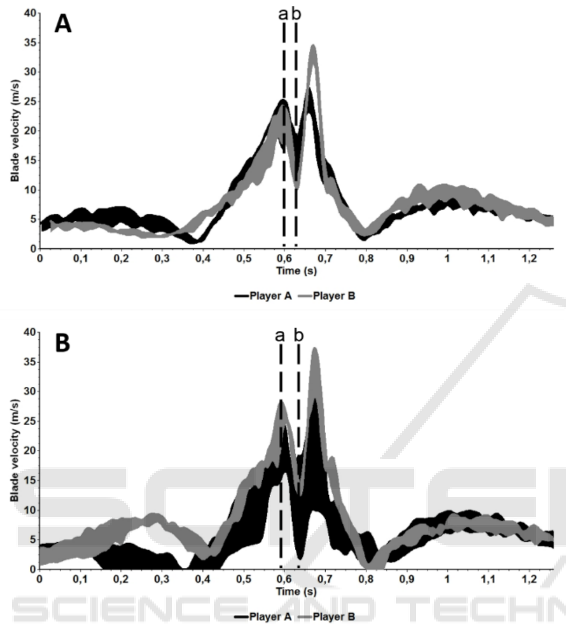

Figure 2: Areas of variance around the mean (±SD) illustrating instantaneous blade velocity for both players for slap shots (A) and for one timers (B). The position for when the blade contacts the ice is represented by the dashed line *a*, and for the puck contact position by the dashed line ***b***.

4 DISCUSSION

In contrast to previous studies, 3D kinematics were successfully acquired from ice hockey shooting exercises on ice by using passive markers and motion capture cameras. The motion capture system allows a higher sampling rate (>240 Hz) compared to previously used measurement systems on ice which have used different setups of video cameras with a sampling rates of 60 – 200 Hz (Goktepe et al., 2010; Lafontaine, 2007).

The results for the slap shot puck velocities and contact times are in line with the results by previous studies (B. T. Kays & Smith, 2017; Lomond, Turcotte, & Pearsall, 2007; Villasenor et al., 2006; Worobets et al., 2006), even if lower puck velocities also have been reported by Wu et al. (2003) and Woo et al. (2004). The characteristics of the blade velocity are shown in Figure 1 A-B and are similar compared to previous studies (B. T. Kays & Smith, 2017; Villasenor et al., 2006).

It is interesting that the trend towards higher puck velocity for one timers is achieved with shorter puck contact time, compared to slap shots. This is most likely accomplished by a higher pre-loading of the stick that increases the stored potential energy in the shaft and affects the puck velocity. However, future studies are necessary to understand the mechanisms which allow similar and even higher puck velocities but with shorter puck contact times.

Neither blade velocity nor stance showed any significant differences between the two shooting techniques. However, it is interesting to note that both players had a higher repeatability, indicated by a lower CV (7% and 9% vs. 34% and 14%), for slap shots compared to one timers, which Figure 1 A-B also demonstrates. Even though no significant difference, it is worth noticing that player B's higher puck velocity for one timers, is achieved without any difference in stance, whereas player A had very similar puck velocities but with a shorter stance with one timers. Future studies should investigate if a maintained stance is a performance indicator to increase one timers shooting performance.

Only two players and two different shooting techniques were analysed, making it difficult to perform any reliable statistical analysis. Still, small differences between the different shooting techniques and players can be detected and analysed by using a motion capture system, such as the one used in the present study.

Even though all markers were placed with great care, several came loose during the trials, most likely due to high accelerations when the stick impacted the ice and the puck. However, if using stronger adhesive tape and additional reflective markers, the motion capture setup in the present paper could be used to analyse stick bending and the recoil effect when shooting on ice. Stick bending and the recoil effect were investigated by Villaseñor et al. (2006) but they only used one high-speed video camera, perpendicular to the sagittal plane, and synthetic ice. Compared to using video cameras, the methodology in the present paper appears to allow detailed 3D kinematic analyses on ice, which entails the correct friction coefficient between the blade and the ice. Previous studies have only used synthetic ice to simulate on-ice condition when analysing stick and puck kinematics during slap, which plausible affects the results (Frayne et al., 2015; B. T. Kays & Smith, 2017; Lomond et al., 2007; Villasenor et al., 2006).

The ability to measure shooting kinematics accurately on ice is vital in order to analyse ice hockey biomechanics and to identify key performance indicators for different shooting techniques. The presented method is shown to perform well for analysing ice hockey kinematics and shooting performance on ice. However, the capturing volume requires a large number or cameras and the long time for setting up cameras should be taken in consideration for future studies. Still, 3D motion capture data enable numerous possibilities to investigate ice hockey shooting kinematics on ice.

5 CONCLUSIONS

The use of a 3D motion capture system, as the one used in the present study has the potential to enable new possibilities to accurately analyse ice-hockey shooting kinematics and shooting performance on ice.

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