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**Penalty corner routines in elite women's indoor field hockey: Prediction of outcomes based on tactical decisions**

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Running title: Penalty corner routines in women's indoor hockey

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## Abstract

Indoor hockey is a highly competitive international sport, yet no research to date has investigated the key actions within this sport. As with outdoor field hockey, penalty corners represent one of the most likely situations in which goals can be scored. All 36 matches of the round-robin phase of the 2010-2011 England Hockey League Women's Premier Division 'Super Sixes' competition were analysed with the purpose of establishing which factors can predict the scoring of a goal using Binary Logistic Regression analysis. Seventy two (22.6%) of the 319 observed penalty corners resulted in a goal. The strongest predictor of scoring a goal was taking the penalty corner from the goalkeeper's right. Based on the odds ratio (OR), the odds of the attacking team scoring were 2.27 (CI = 1.41 - 3.65) times higher with penalty corners taken from the goalkeeper's right as opposed to the left. Additionally, if the goalkeeper decided to rush to the edge of the circle, the odds of the attacking team failing to score were 2.19 (CI = 1.18 - 4.08) times higher compared to when the goalkeeper remained near the goal line. These results suggest that strategic decisions from the players and coaches have an important part to play in the success of penalty corners. Future research should investigate the impact of goalkeepers' movement and further examine the technical and tactical intricacies of penalty corners.

## Introduction

Research related to field hockey has not kept pace with other Olympic sports and has predominantly focussed on injuries, biochemistry, sport injuries and psychology (Podgórski and Pawlak, 2011). Although there has been some work based around cognitive functioning (e.g. Elferick-Gemser, Kannekens, Lyons, Tromp and Visscher, 2009; Konarski, Matuszyński and Strzelczk, 2006), relatively little field hockey research has focussed on coaches' and players' tactical and strategic decision making in relation to performance.

Recent performance analysis research in field hockey has advanced the understanding of movement patterns at the elite level (e.g. MacLeod, Morris, Nevill and Sunderland, 2009), featuring repeated sprint activity (Spencer et al., 2004). Other recent research has investigated the impact of the fundamental rule changes applied to field hockey in recent years concerning the enabling of players to 'self-pass' from free hits (Tromp and Holmes, 2011). A small number of articles have focussed on the actions surrounding penalty corners, with Mosquera, Molinuevo and Roman (2007) comparing scoring actions of elite male and female penalty corners, finding that men predominantly score through a direct drag-flick at goal, whereas women are more likely to score with a direct hit or near-goal deflection, building on the findings of Laird and Sutherland (2003) which emphasised the importance of more direct attempts on goal. Technical consideration of fundamental actions underpinning the penalty corner have also received some consideration with López de Subijana, Juárez, Mallo and Navarro (2010) performing a biomechanical analysis of the drag-flick, whilst Kerr and Ness (2006) analysed the 'push-in' to commence the routine.

Indoor hockey is a popular version of the outdoor game, with the 3rd World Cup held in Poznan in February 2011, which, for the first time, featured representative teams from all five continents (International Hockey Federation [FIH], 2011a). Despite this widespread popularity, virtually no research has been conducted to investigate the unique nuances of this version of the game. Indoor hockey is a six-a-side game most commonly played in a sports hall on a 44 x 22 m pitch with two, 0.10m high boards running down each touchline to keep the ball in play (FIH, 2011b). As with the outdoor game, goals can only be scored from within the shooting circle, with penalty corners being awarded in a similar manner; however, the ball cannot be hit and may only be pushed or flicked. The only time a ball is allowed to be raised is when shooting at goal. Matches comprise two halves of twenty minutes.

In England, the culmination of the Indoor Competition at Wembley Stadium represents one of the premier events in the England Hockey Board's calendar (England Hockey Board [EHB], 2011a). As with the outdoor game, penalty corners play an important part in Indoor Hockey. In the 2011 Women's 'Super Sixes' Premier League, 14 of the 19 goals scored by the two leading scorers in the competition came from penalty corners (EHB, 2011b). To date, no investigation has examined actions surrounding the penalty corner in elite women's indoor hockey. This investigation seeks to identify the tactical factors associated with a successful outcome from penalty corner routines in elite women's indoor field hockey.

Notational analysis continues to represent a widely utilised aspect of performance analysis enjoying increasing prominence within professional practice (O'Donoghue, 2010a). Despite this, Hughes (2004) suggests most notational analysis studies feature insufficiently rigorous statistical analysis, advocating the use of numerous techniques to enhance the value of such research. One of the techniques advocated by both Hughes (2004) and O'Donoghue (2010a) is binary logistic regression. Binary logistic regression is a technique similar to multiple regression, although does not share the same assumptions. Binary logistic regression does not require the relationship between the variables to be linear (Field, 2009). In binary logistic regression, a binary categorical outcome variable can be predicted via any number of predictor variables with each being assigned its own coefficient. The technique also allows consideration of the interaction effect of combinations of predictor variables. The outcome of binary logistic regression is particularly well suited to professional practice as the results can be reported via easily comprehensible odds ratios (OR). ORs are based in the probability of certain events happening and can be calculated by observing the number of times events occur given particular circumstances and dividing this frequency by the number of times the events did not occur (Field, 2009). Although extensively utilised in health research, very few notational analysis studies have applied binary logistic regression, despite the suitability of the technique to the field having been established over the course of the last decade (e.g. O'Donoghue, 2004; 2010b). In one example Marcelino, Mesquita, Palao and Sampaio (2009) sought to establish the probability of winning in volleyball based on the location of the match and used various situational and technical performance-related indicators as potential predictors. Lozovina, Pavičić and Lozovina (2011) investigated 21 potential predictors of successful performance by the Centre Forward in Water Polo; Lozovina et al.'s (2011) study represents the only known investigation to have included some tactical elements

within their analysis. A secondary aim of this investigation is to contribute to the sparse notational analysis literature employing binary logistic regression.

## Methods

### *Sample*

All 36 matches of the round-robin phase of the England Hockey League Women's Premier Division 'Super Sixes' competition were analysed live during the 2010-2011 season using a hand notation system. This competition comprises the nine top indoor sides in England; the round-robin phase producing the four top teams qualifying for the knock-out semi-finals. Approval for the study was granted by the University of Gloucestershire's Research Ethics Sub-committee; athlete performances were in the public domain.

### *Penalty corner analysis*

Each penalty corner was notated by an observer who was positioned in a raised seating area close to the pitch with a clear and unimpeded view of both goals. Data were recorded manually on a sheet featuring a diagram of the shooting circle. One defensive and three offensive (nominal) categories (predictor/independent variables) were identified to represent the full range of strategic and tactically-based decisions that could be made by the respective coaches and/or players at each penalty corner. The defensive variable was the movement of the goalkeeper, whilst the offensive variables were the side the ball was played from, the position around the edge of the circle to which the ball was directed and the routine executed by the attacking team. The defensive pattern at a penalty corner is primarily determined by the action of the goalkeeper, with one defender always guarding each post and the other team members rushing to the edge of the shooting circle to block any attempt on goal. The categories were coded as follows:

*Side:* Whether the ball was injected from the goalkeeper's right or left.

*Injection:* Whether the ball was injected to the near side (perpendicular to the baseline) or the top of the shooting circle.

*Goalkeeper (defensive):* Whether the goalkeeper rushed towards the ball, started to rush and then stopped, or simply held their ground near the goal line.

*Routine:* Eleven routines were identified throughout the course of the 36 matches, based on the action taken at the initial point of control outside the shooting circle:

> *Drag-flick*: a direct, flicked shot from the edge of the circle.
>
> *Move and shot*: the striker dribbles the ball briefly to the attacking team's right before shooting at goal.
>
> *Slip right*: the ball is passed to the next player to the attacking team's right for a direct shot at goal.

*Double slip right*: the ball is passed to the attacking team's right, missing out the closest player, arriving at the next player along for a direct shot at goal.

*Slip left*: the ball is passed to the next player to the attacking team's left for a direct shot at goal.

*Double slip left*: the ball is passed to the attacking team's left, missing out the closest player, arriving at the next player along for a direct shot at goal.

*Wall pass*: the ball is played to the attacking team's right and then returned to the passer who has advanced towards the goal for a direct shot.

*Return to injector*: the ball is passed back to the player who initially injected the ball for an attempted deflection towards the goal.

*Slip right and deflect*: the ball is passed to the attacking team's right and then played towards a teammate moving towards the goal for an attempted deflection towards the goal.

*Slip left and deflect*: the ball is passed to the attacking team's left and then played towards a teammate moving towards the goal for an attempted deflection towards the goal.

*Far post deflection*: the ball is played across the face of goal to a player having moved to the far post for a near-goal deflection.

The outcome of the penalty corner was categorised three times to represent the binary dependent variable (successful/unsuccessful) of three binary logistic regression models. Failure to meet one of the following criteria led to the routine being labelled 'unsuccessful'.

*Model 1 success: Goal*; those routines leading directly to a goal.
*Model 2 success: Goal or upgrade*; those routines leading either to a goal or the award of a penalty stroke.
*Model 3 success: Non-negative*; those routines leading to a goal, penalty stroke, or the re-award of another penalty corner.

This investigation is concerned only with those penalty corner routines which were pre-planned and rehearsed by the attacking team. Therefore, any intervention by the defensive team, even if it did not dispossess the attacking team, was deemed to have ended the routine and so that corner was coded as unsuccessful. For example, an attacking team's attempt which was successfully blocked in the first instance, but nevertheless resulted in a goal because the attacking team picked up the loose ball and scored, was not considered a successful penalty corner routine as it was not pre-planned and rehearsed. Routines which featured a failure to control the ball at the edge of the circle following the push-in or where the goalkeeper had been replaced by a 'kicking back' were excluded from the analysis.

### *Validity of the notation*

Two matches were video-recorded (Sony, DCR-SR32, Tokyo) from a position close to the observer. Each penalty corner within these matches was subsequently coded using the same hand notation system as the live observations to assess the validity of the hand notation system. Agreement of the side, injection, routine and GK variables was 100% ($\kappa = 1.00$). Agreement of the outcome variable was 93.3% ($\kappa = 0.91$).

### *Data analysis*

Data were analysed using SPSS for Windows version 19. Binary logistic regression was used to assess the association of the predictor (independent) variables outlined above with the various outcome (dependent) variables of success. In order to avoid cases with categories involving small numbers, the *routine* variable was re-coded into; direct shot (1 – drag flick), slip then direct shot (2 – move and shot; slip right; slip left; double slip right; double slip left; wall pass) or deflection near to goal (3 – return to injector; slip right and deflect; slip left and deflect; far post deflection). Collinearity diagnostics were calculated and revealed no highly intercorrelating variables (Minimum Tolerance = 0.507; Maximum VIF = 1.972). Analysis was based on the forced entry method as the volume of the data set was not sufficient to validate a stepwise procedure through data splitting (Field, 2009).

## Results

Of the 319 observed penalty corners eligible for inclusion in the analysis, 72 (22.6%) resulted in a goal, five (1.6%) were upgraded to a penalty stroke and 14 (4.4%) were re-awarded as another penalty corner. The remaining 228 (71.5%) were unsuccessful. The majority of corners (N = 242, 75.9%) were injected to the top of the shooting circle with 188 (58.9%) taken from the goalkeeper's right and 131 (41.1%) from the left. The goalkeeper rushed to the top of the circle 163 (51.1%) times, remained near the goal line on 137 (42.9%) occasions and began to rush, but then stopped on 19 (6.0%) attempts. The most common attacking routine was the direct drag-flick taken from the point at which the injection was controlled (N = 203, 63.6%), followed by a slip to the side and a shot from distance (N = 93, 29.2%) and then by near-goal deflections (N = 23, 7.2%).

The majority of goals were scored through direct drag-flicks from point of control (N = 48, 66.7%) with 17 (23.6%) scored following a slipped pass and seven (9.7%) from a near-goal deflection. Most goals came from balls injected to the top of the shooting circle (N = 55, 76.39%) with 17 (23.61%) coming from a near side push-in. Injecting the ball from the goalkeeper's right yielded more goals (N = 41, 56.94%) than from the left (N = 31, 43.06%). Despite this, the probability of scoring from the left was higher than the right with success rates of 23.66% and 21.81% respectively. The defensive teams conceded more goals when the goalkeeper remained close to the goal line (N = 35, 48.61%) as opposed to rushing to the edge of the shooting circle (N = 31, 43.06%) with scoring success rates of 25.55% and 19.02% respectively. Six goals (8.33%) were conceded when the goalkeeper began to rush but then stopped, eliciting a scoring success rate of 31.58%.

The three binary logistic regression models allowed assessment of the impact of the independent variables (i.e., side, injection, goalkeeper and routine) on the likelihood of the attacking team obtaining a successful result. Each of the binary logistic regression models had a single outcome (dependent) variable determining success: 'Goal' (Model 1), 'Goal or upgrade' (Model 2) and 'Non-negative' (Model 3), as listed above. Model 1 demonstrated a significant outcome $\chi^2$ (6, N = 319) = 100.69, $p < 0.001$), indicating the model was able to distinguish between successful and unsuccessful penalty corner attempts. The model explained between 27.1% (Cox and Snell R square) and 36.1% (Naglekerke R square) of the variance and correctly classified 77.1% of cases. As shown in Table 1, only two of the independent variables made a unique, statistically significant, contribution to the model (side and goalkeeper). The strongest predictor of scoring a goal was taking the penalty corner from the goalkeeper's right. Based on the OR, the odds of the attacking team scoring were 2.27 (CI = 1.41 - 3.65) times higher with penalty corners taken from the goalkeeper's right as opposed to the left. Additionally, if the goalkeeper decided to rush to the edge of the circle, the odds of the attacking team failing to score were 2.19 (CI = 1.18 - 4.08) times higher compared to when the goalkeeper remained near the goal line. Note that ORs and CIs of these variables have been inverted from the results displayed in Table 1 for ease of interpretation.

INSERT TABLE 1 HERE

Models 2 and 3 featured the 'Goal and upgrade' and 'Non-negative' outcome variables respectively, revealing similar outcomes to Model 1, although explaining less of the variance and classifying slightly fewer cases correctly. Model 2 demonstrated a significant outcome ($\chi^2$ (6, N = 319) = 89.476, $p < 0.001$), explaining between 24.5% (Cox and Snell R square) and 32.6% (Naglekerke R square) of the variance and correctly classified 75.7% of cases. Model 3 also demonstrated a significant outcome ($\chi^2$ (6, N = 319) = 57.067, $p < 0.001$), explaining between 16.4% (Cox and Snell R square) and 21.8% (Naglekerke R square) of the variance and correctly classified 71.8% of cases. Tables 2 and 3 reveal that the same two independent variables in each case are identified as the statistically significant predictors of a successful outcome, although both models reveal slightly smaller ORs.

INSERT TABLE 2 HERE

INSERT TABLE 3 HERE

The side and goalkeeper variables were not found to be so closely related that they violated the assumption of multicolinearity; however, they were significantly associated ($\chi^2$ (2, N = 319) = 101.22, $p < 0.001$). The goalkeeper rushed to the edge of the circle on 140 (74.5%) occasions when the ball was injected from their right. Conversely, the goalkeeper stayed close to their line on 97 (74.0%) of the occasions when then ball was injected from their left.

**Discussion**

Seventy two (22.6%) of the 319 observed penalty corners resulted in a goal. The strongest predictor of scoring a goal was taking the penalty corner from the goalkeeper's right. Based

on the OR, the odds of the attacking team scoring were 2.27 (CI = 1.41 - 3.65) times higher with penalty corners taken from the goalkeeper's right as opposed to the left. Additionally, if the goalkeeper decided to rush to the edge of the circle, the odds of the attacking team failing to score were 2.19 (CI = 1.18 - 4.08) times higher compared to when the goalkeeper remained near the goal line. These data affirm the importance of encouraging coaches to consider multivariate techniques such as binary logistic regression, rather than rely on univariate approaches. For example, consideration of the 'side' variable alone might lead a coach to favour a strategy of injecting the ball from the goalkeeper's left where the percentage of penalty corner executions which led to a goal slightly exceeds that from the goalkeeper's right (23.66% and 21.81% respectively). However, the three binary logistic regression models have demonstrated that injecting the ball from the goalkeeper's right is more likely to lead to a successful outcome. This opposing view of the binary logistic regression models is of greater value because multivariate approaches take into account relationships between variables such as the significant association between the side and goalkeeper variable and are, therefore, able to make predictions with a more complete view of the external influences (Field, 2009). Nevertheless, future research should further investigate the relationship between the side and goalkeeper variables.

The findings of the present study demonstrate the importance of coaches' and players' tactical and strategic decisions relating to the execution of penalty corners in elite women's indoor hockey. Considering that between 71.8% (Model 3) and 77.1% (Model 1) of penalty corners can be correctly classified using the independent variables listed in this study, it can be seen that these tactical and strategic decisions are vital for a successful outcome. This is reinforced by the considerable variance explained within these models (Pallant, 2010), and particularly in Model 1 (27.1% - 36.1%), although this still leaves plenty of scope for other technical factors which are doubtless a crucial component. An important contextual factor was the consistently high standard of execution in attacking routine at this level of play – just 25 (7.2%) of penalty corner routines broke down because of an attacking mistake (mis-trap). Although there is no directly comparable data, this error rate is lower than that reported in investigating attacking patterns in elite level volleyball (Monteiro, Mesquita and Marcelino, 2009), although the penalty corner in indoor hockey arguably presents a more 'closed' environment for skill execution.

The patterns of the offensive actions and routines are different from those reported in literature concerning outdoor hockey. Mosquera et al. (2007) and Laird and Sutherland (2003) both suggested that women's hockey featured less direct efforts on goal, with fewer drag-flicks and more near-goal deflections. These findings reveal the pattern of offensive penalty corners in women's indoor hockey is somewhat different. Just 23 (7.2%) routines featured a near-goal deflection resulting in seven (9.2%) of the goals scored. The predominance of the drag-flick in terms of the volume of its strategic deployment and the number of goals scored reveal that the relative prevalence of this action compared to the outdoor game. It may be that the shorter distance to goal and the lighter ball allows athletes to propel a more powerful and effective shot than can be achieved outdoors. López de Subijana et al. (2010) reported elite female athletes to generate a substantially slower ball

speed than their male counterparts. The applicability of these findings to the outdoor scenario and the male game requires further investigation. The findings relating to the side from which the ball is injected being a significant predictor of success is unique to this setting and has limited application to other sporting environments or to previous research, but is nonetheless useful to those coaches and players making tactical decisions in indoor hockey.

The tactical and strategic decision making of goalkeepers has not previously been considered. This investigation has shown that the action of the goalkeeper is a significant predictor of the outcome of the penalty corner in elite women's indoor hockey, suggesting the odds of the opposition reporting an unsuccessful outcome if the goalkeeper rushes to the edge of the circle are higher than if the goalkeeper stays on the goal line. Investigations in hockey can learn from recent research in soccer (e.g. Masters, van der Kamp and Jackson, 2007) which has suggested that goalkeepers' movement may impact the outcome at set pieces. Wood and Wilson (2010) tracked the eye movement of penalty takers in soccer finding that players were more distracted by a moving goalkeeper and that the resultant kick was more likely to be aimed centrally. The impact of a goalkeeper's movement in indoor hockey should be investigated further in this way.

**Conclusion**

As the first notational analysis of elite women's indoor hockey, these data offer an original insight into a key area of this popular and highly competitive sport. This investigation highlights the subtle, but crucial, differences in factors that influence the likely outcome of penalty corners and so have an important message which coaches and players should consider. These data also reveal, through the insight relating to goalkeeper action and the side of injection, that indoor hockey has the potential to yield some original and interesting contributions to the performance analysis literature.

Extending this research to future competitions at this level will result in a much larger data set which should enable the intricacies of the attacking routine and outcome variables to be investigated more thoroughly. Small counts in many routines forced the reduction of the eleven observed categories into three broad codes. Therefore, the complexity of these events has, to a certain extent, been lost and this should be rectified with further investigation. Furthermore, the technical components of the indoor penalty corner should also be analysed further, including the speed and direction of the shot on goal in terms of the likelihood of these elements contributing to a successful outcome. The independence of attacking routines in this investigation was assumed due to the high volume of personnel interchanges involved in indoor hockey. The high number of interchanges means that the likelihood of any one combination of attacking personnel being matched against the identical combination of defensive players, is very low; however, future research should seek to confirm this assumption.

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Table 1: Factors associated with the outcome of scoring of a goal from a penalty corner

| | B | S.E. | Wald | df | P | OR | 95% CI for Odds Ratio | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Lower | Upper |
| Side (1) | -.819 | .243 | 11.310 | 1 | .001 | .441 | .274 | .711 |
| Injection (1) | -.460 | .251 | 3.360 | 1 | .067 | .631 | .386 | 1.032 |
| GK | | | 6.573 | 2 | .037 | | | |
| GK(1) | .127 | .539 | .055 | 1 | .814 | 1.135 | .395 | 3.262 |
| GK(2) | -.785 | .317 | 6.124 | 1 | .013 | .456 | .245 | .849 |
| Routine | | | 2.407 | 2 | .300 | | | |
| Routine(1) | -.446 | .318 | 1.968 | 1 | .161 | .640 | .343 | 1.194 |
| Routine(2) | .236 | .505 | .219 | 1 | .640 | 1.267 | .471 | 3.409 |

*Note:* Reference categories are: Side (goalkeeper's right), Injection (near side), GK (stays on line) and Routine (direct shot). Alternative GK categories are: starts to rush then stops (1) and rushes to edge of the circle (2). Alternative Routine categories are: slip then direct shot (1) and deflection near to goal (2).

Table 2: Factors associated with an outcome of an 'upgrade' to penalty stroke or scoring a goal from a penalty corner

| | B | S.E. | Wald | df | p | OR | 95% CI for Odds Ratio | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Lower | Upper |
| Side (1) | -.804 | .240 | 11.215 | 1 | .001 | .448 | .280 | .717 |
| Injection (1) | -.342 | .247 | 1.909 | 1 | .167 | .711 | .438 | 1.154 |
| GK | | | 6.574 | 2 | .037 | | | |
| GK(1) | .070 | .537 | .017 | 1 | .897 | 1.072 | .374 | 3.071 |
| GK(2) | -.775 | .310 | 6.253 | 1 | .012 | .460 | .251 | .846 |
| Routine | | | 2.546 | 2 | .280 | | | |
| Routine(1) | -.463 | .310 | 2.226 | 1 | .136 | .629 | .343 | 1.156 |
| Routine(2) | .184 | .503 | .134 | 1 | .714 | 1.202 | .449 | 3.220 |

Table 3: Factors which predict a 'Non negative' result from a penalty corner

| | B | S.E. | Wald | df | p | OR | 95% CI for Odds Ratio | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Lower | Upper |
| Side (1) | -.661 | .228 | 8.433 | 1 | .004 | .516 | .331 | .807 |
| Injection (1) | -.311 | .239 | 1.686 | 1 | .194 | .733 | .458 | 1.172 |
| GK | | | 4.495 | 2 | .106 | | | |
| GK(1) | -.208 | .528 | .155 | 1 | .694 | .812 | .289 | 2.287 |
| GK(2) | -.625 | .295 | 4.493 | 1 | .034 | .535 | .300 | .954 |
| Routine | | | .377 | 2 | .828 | | | |
| Routine(1) | -.096 | .280 | .118 | 1 | .732 | .909 | .525 | 1.571 |
| Routine(2) | .220 | .484 | .206 | 1 | .650 | 1.246 | .483 | 3.215 |