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ORIGINAL ARTICLE

Game-Related Statistics Discriminate between Winning and Losing Teams in the Field Hockey

[1]Amritashish Bagchi*, [2]Shailesh Singh, [1]Shiny Raizada, [1]Anurag Reddy, [1]Nayana Nimkar

[1]Symbiosis School of Sports Sciences, Symbiosis International (Deemed University), Pune, Maharashtra, India. [2]Sports Authority of India, Netaji Subhas National Insitute of Sports, Patiala, Punjab, India.

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ABSTRACT

Background. There is a dearth of literature on match analysis in field hockey. Time-motion analysis, the relationship between play patterns and goal-scoring opportunities, and penalty corner strategies are currently available in the literature on field hockey**.** Nevertheless, none of the studies have identified the factors contributing to winning. These factors could be used to help coaches develop a specific training schedule, monitor playing patterns, improve player selection processes, specify each player's role, and evaluate their overall performance. **Objectives.** The present study aimed to identify game-related statistics in Field Hockey that best discriminate between winning and losing teams. The data was gathered from the 2018 Men's Hockey World Cup matches. **Methods.** The grouping variable selected for this study was Match Results (i.e., Win/Lose). Whereas the selected game-related statistics were Ball Possession, Shots Attempted, Pass Accuracy, Circle Entries, and Penalty Corner. A total of 36 matches were analyzed. Independent samples t-test was used to compare the mean difference and discriminant analysis was applied to identify the game-related statistics that best discriminate between winning and losing teams. **Results.** The Results have shown a significant ($p<0.05$) mean difference for all the selected game-related statistics and the developed discriminant model was also found to be significant ($p=0.000$). The interpretation of the generated discriminant functions was examined based on the Structure Coefficients (SC) $\geq |0.30|$. **Conclusion.** According to the statistical significance of the model and SC, the variables which majorly contributed to discriminating between winning and losing teams were circle entries (SC=.663), ball possession (SC=.415) and shots attempted (SC=.307). Winning teams were examined to be ahead of losing teams in all the game-related statistics.
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KEYWORDS: ***Field Hockey, Game-related Statistics, Discriminant Analysis, Win and Loss.***

INTRODUCTION

Field hockey is a team sport comprised of the implementation of a variety of techniques like trapping and receiving, passing, dribbling, leading, tackling and intercepting, goal shooting, and goalkeeping (1). Players must use these skills in various scenarios throughout the game. Coaches and performance analysts study their teams' and players' performances using these game-related statistics in different contexts. In performance analysis, it is essential to consider game-related statistics, and their levels may be affected by the characteristics of the players and their training experience. As technology is revolutionizing sports performance by live-

*. Corresponding Author:
Amritashish Bagchi, Ph.D.
E-mail: amritashish.bagchi@ssss.edu.in

tracking that provides real-time analysis of all the game-related statistics, it has substantially increased athletic potential (2). Most game-related statistics are influenced by multiple factors, such as defensive and offensive tactics, resulting in a complex dynamic system during the game, which is difficult to control as a whole (3).

Performance analysis aims to gather all the variables that influence sports strategy and present them in a clear, understandable, and comprehensible manner. The ability to capture in-game events in great detail is essential for providing effective and practical insight into strategy. Systems for computerized notational analysis were designed to collect in-game activities and ball-tracking statistics from Field Hockey matches (4). In performance analysis, it is essential to consider game-related statistics, and their levels may be affected by the characteristics of the players and their training experience. Most game-related statistics are influenced by multiple factors, such as defensive and offensive tactics, resulting in a complex dynamic system during the game, which is difficult to control as a whole (5). Performance/match analysis in the sport using game-related statistics aims to identify the strengths and weaknesses of a team or player, which can be developed further and become more effective. Similarly, when analyzing an opponent's performance, the coach/analyst will exploit the opponent's weaknesses and identify ways to counter their strengths (5). In particular, game-related statistics help distinguish successful teams from unsuccessful ones by providing reliable information about the teams' performance to the coaches (3). Researchers, statisticians, and analysts in sports have identified Game-Related Statistics of a team or an individual in a game and then developed different models based on the selected variables. These models help the coaches to make better match strategies and tactics for the team's success (6–9) and also forecast the future of sporting activity (10–12). It will also assist in better team selection based on KPIs (Key Performance Indicators) that are more important and have high weightage compared to the other parameters (KPI).

Earlier studies were carried out in sports like basketball, rugby, soccer, and NHL to identify the game-related statistics or performance indicators that distinguished between a successful and unsuccessful team or a player. Previous investigations extensively examined Game-related statistics in the following categories: a) primarily to evaluate team performance and determine the most valuable player, b) the effect of home advantage (12) and location impact on different teams' final scores (14, 15), c) an analysis of the NBA guards, forwards, and centers (16), d) comparison of the starters and bench players in Women's NBA (10), e) evaluation of teams in FIBA and men's U-16 basketball based on scoring strategies (17). Several game-related statistics have been used in basketball, but only some are considered essential. Lago-Peñas et al. extensively examined game-related statistics in Spanish Soccer League. They found that assists, shots on goal, total shots, ball possession, crosses and crosses against, and venue were the discriminating factors in winning and losing teams (18). Along similar lines, with the help of logistic regression, researchers found out that total goals, total assisted goals, and total shots taken were significant contributing factors for the teams to win in NHL (Ice hockey) (19).

No such studies have been done in field hockey for categorizing match results based on game-related statistics. Currently, available literature in field hockey covers time-motion analysis, the relationship of playing patterns with goal-scoring opportunities, and penalty corner strategies (20, 21). However, there is a dearth of literature on match analysis in field hockey. The purpose of the present study was to determine the game-related statistics in field hockey that best discriminate between winning and losing teams.

MATERIALS AND METHODS

In the year 2018, International Hockey Federation (FIH) increased the number of teams, from 12 to 16 teams, that participated in the World Cup tournament. The teams that participated in the tournament were Argentina, Australia, Belgium, Canada, China, England, France, Germany, India, Ireland, Malaysia, Netherlands, New Zealand, Pakistan, South Africa, and Spain. This was done to increase the number of matches available for spectator viewing. Before 2018, the Men’s Hockey World cup consisted of two pools (A and B) containing six teams each. Whereas, in the 2018 Men’s Hockey World Cup there were four pools each consisting of four teams. After applying inclusion and exclusion criteria, a total of 27 matches' data (i.e. 54 observations per variable for winning and losing teams) were collected. These 27 matches’ data were made up of the winning teams’ (N = 27) and the losing teams’ (N = 27) data.

Data Collection Procedures. For this study, the data was collected from the publicly available official website (http://www.fih.ch/) of the International Hockey Federation (FIH). For the study, the data was collected from the 2018 Men's Hockey World Cup matches played in Bhubaneshwar, Odisha, India. The Game-related statistics of the 2018 Men's Hockey World cup for all 36 matches were recorded in the excel sheet. Data for matches (nine matches) that were drawn (inconclusive winner) or results that were decided by penalties were not included in the study. The grouping variable selected for the study was match results i.e., win/lose. Whereas the selected game-related statistics (independent variables) were Ball Possession, Shots Attempted, Pass Accuracy, Circle Entries, and Penalty Corner:

A) Ball possession is defined as the physical control of the ball by a team in the game of field hockey.
B) Shots attempted, in field hockey, are defined as clear attempts to score a goal by a player
C) Pass accuracy is the potentiality of a ball to be passed accurately to a target - it could be to another player or a goal.
D) Circle entries in a game of field hockey is the number of entries into the shooting circle (attacking D) made by an attacking team.
E) Penalty corners are awarded to an attacking team for fouls or defensive errors committed by the defending team in their defensive D.

Statistical Analysis. Descriptive statistics were used for understanding the nature of the selected data. Independent sample t-test and Mann-Whitney U Test were carried out for comparing the game-related statistics of winning and losing teams. The effect size was calculated to analyze the magnitude of the significance. Pearson product-moment correlation coefficient and R2 were computed (only for the winning team data) to find out the relationship between the selected game-related statistics. Discriminant analysis was used to find the contribution of all the game-related statistics for classifying Match Results (Win/Loss) and to develop a discriminant model. SPSS Version 24 was used for conducting statistical tests and analyzing the data. For all the statistical analyses the level of significance was observed at 0.05.

RESULTS

Table 1 demonstrates the comparison of mean and standard deviation (SD) values of all the game-related statistics of all the teams that participated in the league.

Table 1. Mean and SD of the Game Related Statistics of teams that participated in the league.

S.No	Team	Matches Won	Ball Possession (%)	Shots	Pass Accuracy (%)	Circle Entries	Penalty Corner
1	**Argentina**	2	48.5625±7.98	7.75±2.22	61.28±7.85	17±4.97	4.25±0.96
2	**Australia**	5	53.15±3.46	12.4±5.6	69.08±4.01	26±8.34	5±1.22
3	**Belgium**	5	52.95±2.81	13.8±3.11	70.484±4.46	27.2±6.06	5.4±2.88
4	**Canada**	0	47.83±2.47	2.67±1.15	59.84±4.62	6±1.00	2.67±3.79
5	**China**	0	42.625±0.18	2±1.41	55.015±1.79	7.5±4.95	2±1.41
6	**England**	3	49.59±2.68	6.83±2.23	66.37±3.22	17±6.63	3.33±1.75
7	**France**	2	54.94±2.29	10.25±7.18	65.25±3.83	22±9.87	4.5±2.38
8	**Germany**	3	52.63±5.66	9.75±4.65	66.745±4.12	23.5±11.82	3.25±3.59
9	**India**	2	55.58±1.01	10.67±4.51	63.34±6.43	27±13.11	3.67±1.53
10	**Ireland**	0	46.375±1.24	4.5±2.12	63.425±2.78	8.5±3.54	2.5±2.12
11	**Malaysia**	0	45.125±2.30	4±2.83	55.905±1.55	11±11.31	4.5±4.95
12	**Netherlands**	4	49.15±5.38	14±8.46	63.938±6.09	31.2±7.12	6±2.35
13	**New Zealand**	1	45.1±4.67	7±4.00	60.97±4.00	16.33±2.52	1.67±1.53
14	**Pakistan**	0	47±3.68	4.67±2.89	57.06±5.14	10±5.29	2.33±2.52
15	**South Africa**	0	44.25±1.06	5.5±0.71	63.36±3.03	12.5±3.54	1±1.41
16	**Spain***	0	58	8	74.1	17	2

***Spain has played only one match hence standard deviation value can't be generated.

Table 2 demonstrates the mean and standard deviation along with skewness and kurtosis value of all the game-related statistics between winning and losing teams.

The data for all the game-related statistics were found to be normally distributed (Table 2) as the skewness and kurtosis values were less than twice their standard error value.

Table 3 shows significant correlation coefficient values for most of the pairs. There is a high positive correlation (0.70 – 0.89) between two of the pairs i.e., 1) Circle entries and shot attempted (0.733) & 2) Ball Possession and Pass accuracy (0.701). Four pairs were found to have a moderate positive correlation (0.50 – 0.69) and one pair had a low positive correlation (0.421). The coefficient of determination (R2) value represents the percentage of variance explained.

For comparing the game-related statistics (such as Ball Possession, Pass Accuracy, Circle Entries, and Penalty Corners) of winning and losing teams, an independent sample t-test was carried out (Table 4). For Shots Attempted, Mann Whitney U-test was used as the data was found to be heterogeneous. Cohen's d (effect size) was calculated for all the game-related statistics except for Shots Attempted (Eta Squared). All the game-related statistics showed a significant difference ($p<0.05$). Circle entries, ball possession, and shots attempted were found to have a very large effect size (Cohen's $d \geq 1.30$; Eta Squared > 0.14) value. While penalty corner and pass accuracy percentage had a large effect size (Cohen's $d \geq 0.80$).

Table 2. Descriptive Results of the Game-Related Statistics for Men's Hockey World Cup 2018.

Match Results		Ball Possession %age	Shots Attempted	Pass Accuracy %age	Circle Entries	Penalty Corners
Win	**Mean**	52.780	12.259	66.615	26.185	4.85
	SD	4.305	5.2447	5.669	8.417	2.282
	Skewness	-.905	.395	-.820	.174	-.055
	Std. Error of Skewness	.448	.448	.448	.448	.448
	Kurtosis	.749	.037	1.110	-.889	-.227
	Std. Error of Kurtosis	.872	.872	.872	.872	.872
Loss	**Mean**	47.202	5.074	61.605	12.630	2.67
	SD	4.280	2.401	5.344	6.325	2.166
	Skewness	.939	.410	.258	.486	.760
	Std. Error of Skewness	.448	.448	.448	.448	.448
	Kurtosis	.855	-.041	.227	.060	.008
	Std. Error of Kurtosis	.872	.872	.872	.872	.872

Table 3. Correlation Coefficient and R2 between Game-Related Statistics of Winning Team.

Game Related Statistics	Ball Possession %age	Shots Attempted	Pass Accuracy %age	Circle Entries	Penalty Corner
Ball Possession %age	1				
Shots Attempted	.524** (27%)	1			
Pass Accuracy %age	.701** (49.14%)	.519** (26.93%)	1		
Circle Entries	0.362 (13.1%)	.733** (53.72%)	.511** (26.11%)	1	
Penalty Corner	0.254 (6.45%)	.421* (17.72%)	0.314 (9.85%)	.602** (36.24%)	1

** $p < 0.01$ level (2-tailed)

* $p < 0.05$ level (2-tailed)

Table 4. Results of Independent t-test and Mann-Whitney U Test along with its Effect Size.

Game Related Statistics	Levene's Test Sig. value	Independent t-test Sig. value	Mann Whitney U Test Sig. value	Effect Size
Ball Possession %age	.938	.000	NA	1.30
Shots Attempted	.001	NA	.000	0.487*
Pass Accuracy %age	.885	.002	NA	0.909
Circle Entries	.098	.000	NA	1.823
Penalty Corner	.962	.001	NA	0.980

*Eta Squared statistics; very large effect size

The developed discriminant model was found to be significant ($p<0.001$). The interpretation of the generated discriminant functions (Table 5) was examined based on the Structure Coefficients (SC) ≥ |.30|. According to the statistical significance of the model and SC, out of the 5 game-related statistics, the variables that majorly contributed to discriminating between the winning and losing teams are circle entries (SC = .633), ball possession (SC =.415) and shots attempted (SC=.307). 83.3% of the match results were correctly classified by the model. 52.56% (R2) of the variance in the match results was explained by the selected game-related statistics altogether.

Table 5. Discriminant function Structure Coefficients (SC) and tests of statistical significance.

Game Related Statistics	Function 1
Ball Possession %age	0.415*
Shots Attempted	0.307*
Pass Accuracy %age	-0.141
Circle Entries	0.633*
Penalty Corner	-0.040
Box M (Sig.)	0.088
Eigenvalue	1.107
Wilks Lambda	0.475
Canonical Correlation	0.725
Chi-Square	36.897
Significance	< 0.001
Reclassification	83.30%

*SC discriminant value ≥|.30|

The results from the present study indicate that all the selected game-related statistics play an important role in classifying winning and losing teams. The winning teams were significantly ahead of the losing teams in all the selected game-related statistics.

DISCUSSION

The study examined the hypothesis that the selected game-related statistics do contributes to discriminating between the winning and losing teams in Field Hockey. The results demonstrate that the winners were significantly ahead of the losing teams in all the selected (ball possessions, circle entries, penalty corners, and shots attempted) game-related statistics.

Keeping possession of the ball consistently in a 60-minute game is crucial for any team because it creates more goal-scoring opportunities for the team. A defensively strong team that doesn't achieve many goals may have an edge in the playoffs over one that is offensively strong but lacking in defense. The evidence indicates that preventing scoring throughout the season is more important than scoring goals because winning relies on this. As a result, Ball Possessions measure a club's defensive mindset, demonstrating that defense is more important than offense, despite its less glamorous nature (22). So, ball possession is the best performance indicator in the sports like field hockey and soccer (23, 24).

Ball possession directly correlates with game-related statistics such as pass accuracy and attempted shots. If there is no accuracy in ball passing, there are high chances of losing the ball possession, thereby losing the goal-scoring opportunity. Pass accuracy is vital in any ball game for creating more opportunities. Pass accuracy also helps cover the maximum distance quickly and score a goal (25). Passing the ball accurately and directly through the middle of the field gives you more opportunities to score goals before the opposition can assemble their defense. Vinson and Peters (26) found that successful passing was significantly lower in bottom-table teams than in mid-table and qualifying teams in the women's England Hockey premier league. The same can be understood by looking at the correlation table (Table 3), which reflects that the higher the pass accuracy percentage is, the more the ball possession and the greater the chances of

entering the circle and taking shots. To increase their scoring chances, teams aim to move the ball along the baseline to the center of the circle, where the angle and proximity to the goal allow them to score. Sofwan et al. (27) extensively investigated the playing pattern between winning and losing field hockey teams and found a significant difference in circle penetration from the left and right sides between winning and losing teams. Because most players attack with their right hand, the right-side penetration showed the highest results. It indicates that the winning team controlled the circle penetration better, particularly from the right. Regarding center circle penetration, there was no significant difference between winning and losing teams. Left penetration has a slight difference in frequencies compared with right-side penetration, making it an alternative option. Stöck and Morgan (28) analyzed the spatial characteristics of attack in field hockey. The researchers mentioned that left-sided ball possession has more chances to penetrate the shooting circle, although less frequent.

In field hockey, the team attacks to enter the shooting circle; this enhances the chances of taking a shot or getting a penalty corner and scoring a goal (29). Penalty corners are crucial and can usually change the match results at any point in the game. It is one of the most likely conditions in a field hockey game. Studies have observed that the success ratio of penalty corners in scoring a goal is around 29% (30, 31). The success of the penalty corner depends on the goal scored and how it is scored. Laird & Sutherland (32) analyzed two hundred and fifty penalty corners and found that it is less likely that a successful goal will be scored at penalty corners when the ball is hit without leaving the ground.

Compared to lifted balls, balls that are hit without leaving the ground are more likely to be blocked by defenders or saved by goalies. More successful goals are scored from straight shots. Players involved in taking penalty corners must develop these skills to make each corner a potential opportunity for scoring a goal.

Circle entries are the main contributor to obtaining a penalty corner in a field hockey game (30). The same can be seen from the above table (Table 3), as there is a significant positive correlation between circle entries and penalty corners. A player needs to take a shot to score a goal, and as the ultimate aim is to win the match by scoring more goals, all the independent variables have a direct relationship with the Shots Attempted.

CONCLUSION

Game-related statistics in sports are seen as an essential factor that empowers analysts to gather target data that can be utilized by coaches to improve the execution and performance of a player or a team. This study aimed to identify the differences in game-related statistics between winning and losing teams of FIH 2018 Men's Hockey World Cup matches. Findings indicated that all the independent variables contribute to discriminating between winning and losing teams. Circle entries, ball possession and shots attempted were the most valuable game-related statistics selected by the model. Winning teams are way ahead of losing teams in all the game-related statistics with a large to very large effect size. 83.3% of the match results were correctly classified by the developed discriminant model. This study presented a result that may help coaches to develop a specific training schedule, monitor different playing patterns, and improve the player selection process. Coaches can use this information to specify the role of each player and evaluate their performance post-match. This could improve the overall team performance and increase the chances of winning.

One of the limitations of this study could be that the total number of matches played in the tournament is 36 (i.e. 72 observations per variable for winning and losing teams altogether). A ratio of 20 observations for each independent variable is recommended by many researchers. The availability of game-related statistics is minimal compared to other team sports like soccer and basketball.

APPLICABLE REMARKS

- Enhance the importance of the selected game-related statistics in field hockey.
- Assists coaches and trainers to design more specific training programs in Field Hockey.
- Assists coaches to focus on different players' contributions to team performance.

AUTHORS' CONTRIBUTIONS

Study Concept and Design: Amritashish Bagchi. *Acquisition of data:* Shailesh Kumar Singh. *Analysis and interpretation of data:* Amritashish Bagchi, Shiny Raizada. *Drafting of manuscript:* Shailesh Kumar Singh, Shiny

Raizada, Amritashish Bagchi. *Critical revision of the manuscript for important information*: Anurag Reddy, Nayana Nimkar. *Statistical analysis:* Shiny Raizada, Amritashish Bagchi. *Administrative, technical, and material support:* Shiny Raizada, Nayana Nimkar. *Study supervision:* Nayana Nimkar.

CONFLICT OF INTEREST

This manuscript contains no material that could be considered a conflict of interest by the authors.

FINANCIAL DISCLOSURE

There are no financial interests associated with this submission.

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