ANALYSIS OF PENALTY CORNER OF INDIAN TEAM AS COMPARED TO FOREIGN COUNTERPARTS IN THE FIELD HOCKEY: A BIOMECHANICAL STUDY

ABSTRACT

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ABSTRACT

Introduction

Hockey is an outdoor team sport, like football (soccer) and cricket (Kundra, Deepmala & Bedi, 2010). It is played between two groups of eleven players each, on a turf (grassy/synthetic) or a hard mud surface, with hooked or bent sticks and a hard ball (Avest, 2010; Narang, 2005). The object is to drive the ball into the opponents' goal by hitting it with the stick (Thani, 2006). The game is also called 'field hockey' to distinguish it from 'ice hockey', which is very similar but much faster game played on the hard frozen surface of ice, 'roller hockey' 'indoor hokey' and 'street hockey' (Hockey in India, 2012). Although hockey is not played in as many countries as football (Murtaugh, 2001), nor it is as popular. It is one of the team sports included in the programme of the Olympics. Hockey is the national game of India and since 1947 of Pakistan (Sanyal, 1972).

The game hockey indeed said to be the oldest of all games played with a ball and stick. It has a thrill of romantic journey travelling around the world. Persia (Iran) is known to be the birth place of hockey. The Greek borrowed the idea of the game from Persians and in turn passed it on the Romans. It then travelled to France and eventually it found its way to Britain. Hockey was brought to India by the English men towards the end of 19th century (Kundra, Deepmala & Bedi, 2010; Sanyal, 1972).

Games and sports have always been occupied a significant position in the cultural fabric of India. The sportspersons who bring laurels to the country in any sporting event are highly commended and provided a special place in the society. Hockey being a national game of our county
obviously considered a game of masses wherein India reigned supreme starting from its debut in 1928 till 1960 Olympics when they first time lost to its neighbour Pakistan in the finals and secured runners-up position (Genesh, 2005; Singh, 1997; Singh & Walia, 1995). Later on in due course of time India regained its lost glory at Tokyo Olympics in 1964. Thereafter an unprecedented decline in the performance of our hockey team started and in subsequent Olympics in 1968 at Mexico, 1972 at Munich and 1976 at Montreal we could not justified our previous achievements (Genesh, 2005). The experts believe that there have been numerous potential causes responsible to this decline in our performance which include prompt changes in the rules of the game, change of surface and introduction of Astroturf and foremost the development of hockey in other nations in a very systematic and scientific manner (Manna, Khanna & Dhara, 2009; Astorino, Tam, Rietschel, Johnson & Freedman, 2004; Lemmink, Mulder, Elferink-Gemser & Visscher, 2004; Spencer, Bishop & Lawrence, 2004).

Inspite of the declined performance of our teams in premier tournaments, we are still being considered one of the powerful teams globally. With the advent of Astroturf the very nature of the game has totally changed (Caple, James & Bartlett, 2012a; Caple, James & Bartlett, 2012b). The span of playing age remarkably reduced owing to the fighting fit physical fitness (Bartlett, 2001), tremendous speed and other required genetic endowments (Boddington, Lambert, Gibson & Noakes, 2002; Lyle, 2002; Reilly & Borrie, 1992; Wilsmore & Curtis, 1992). As far as the techno-tactical aspect of hockey is considered numerous significant techniques and skills have been emerged that have added tremendous speed to the game thereby there remained no room for slow and unfit players (Joseph, 2012; Boyle, Mahoney & Wallace, 1994). In present day game of hockey merely techno-tactical soundness for which India used to
be considered best throughout the world is not enough (Hussain, 2012; Button, Davids & Schollhorn, 2006). There is need to learn and develop all those factors to the level of mastery on which present day performance in hockey lies (Schokman, Rossignol & Sparrow, 2002; Law, 1990).

Now keeping in view the demand of the game a few new systems of play have also been developed (El-Maati, 2011; Caljouw, Kamp & Savelsbergh, 2004). Beside these systems numerous set plays including taking and defending penalty corner and penalty stroke play a decisive role in winning major competitions and of these penalty corner is considered to be the main weapon for getting goals during the course of competitions (Hussain, Ahmed & Khan, 2012; Meulman, Berger, Zande, Kok, Ottevanger & Crucq, 2012; DeSubijana, Juarez, Mallo & Navarro, 2011; DeSubijana, Juarez, Mallo & Navarro, 2010; Laird & Sutherland, 2003). Most of the major hockey playing countries such as Australia, Netherlands, Germany, Spain, England and Argentina, have been assigning special weightage to train the experts of penalty corner who could convert every chance of penalty corner into a goal (Canal-Brueland, Kamp, Arkestijn, Janssen, Kesteren & Savelsbergh, 2010). The major hockey playing countries of Asia, including Pakistan, South Korea, China, Malaysia and of course India have also been making all sort of efforts to bring improvement in this department of the game but of no much avail as they succeed only here and there without any constant results.

There have been various combinations and tactics to convert penalty corner into goal but in recent time drag-flick is considered the most successful tactical method in scoring goals though penalty corner (Sampedro, Pineiro & Refoyo, 2008; Yosoff, Hasan & Wilson, 2008; Pineiro, Sampedro & Refoyo, 2007; McLaughlin, 1997). Therefore every hockey playing country has been focusing to specially train a few penalty
corner experts who could prove goal getters during the course of competitions (Sofwan, Norasrudin, Redzuan & Mubin, 2012). Hence the present researcher has ventured to compare the execution methods of drag-flick being adapted by the Indian experts and the experts of foreign teams including Australia, Germany, Netherlands, Spain and England. Therefore a biomechanical analysis of the skill (drag-flick) deemed to be most appropriate in order to exactly pin-point the biomechanical differences in the execution of drag-flick at the time of penalty corner of our players to that of the players of foreign teams.

**Statement of the Problem**

In view of the negligible conversion rate of Indian players through penalty corner, existed paucity of research in the biomechanics of the penalty corner and unavailability of scientific data concerning with penalty corner of international caliber the researcher has designed the present study and stated as “Analysis of Penalty Corner of Indian Team as Compared to Foreign Counterparts in the Field Hockey: A Biomechanical Study” in order to pin-point the shortcoming in the execution of penalty corner by our players and thus to evolve corrective measures for proper improvement in its execution.

**Definitions of the Operational Terms**

In order to clarify the respective meaning of the terms employed in the present study the operational definitions have been forwarded as under:
Field Hockey: Field hockey is a team sport in which a team of players attempt to score goals by hitting, pushing or flicking the ball with hockey sticks into the opposing team's goal. Its official name is simply hockey, and this is the common name for it in many countries. However, the name field hockey is used in countries where the word hockey is usually reserved for another form of hockey, such as ice hockey or indoor hockey or street hockey.

Goalkeeper: One of the participants of each team on the field who wears full protective equipment comprising at least headgear, leg guards and kickers and who is also permitted to wear goalkeeping hand protectors and other protective equipment.

Attacker: The team player who is trying to score a goal.

Defender: The team player who is trying to prevent a goal being scored.

Circle: The area enclosed by and including the two quarter circles and the lines joining them at each end of the field opposite the centre of the back-lines. It is also called 'D'.

23 Meters Area (25 Yards Area): The area enclosed by and including the line across the field 22.90 meters from each back-line, the relevant part of the side-lines, and the back-line.

Penalty Corner: The penalty corner is a special and important phase in the development of a field hockey match. Also called 'PC' or short corner or 'penalty', it is awarded to the offending team when the defending team committed a
foul in its circle or a particularly bad foul in its defending quarter (23 meters area).

**Pusher:** One of the participants of the attacking team who pushes the ball from backline to top of the circle at the time of penalty corner execution.

**Stopper:** One of the participants of the attacking team who stops the ball at the top of the circle on a penalty corner execution.

**Drag-flicker:** The player who propel the ball into the goal by flicking the ball.

**Sports Biomechanics:** Sports Biomechanics is a quantitative based study and analysis of professional athletes and sports.

**Biomechanical Analysis:** The biomechanics is concerned with the muscular and mechanical aspect. In the muscular aspect we are concerned with the muscles, bone, joint, and movement of various segments of the body. In the mechanical aspect we deal with the kinematics and kinetics variables i.e. distance, speed, velocity, mass, inertia, force etc. Mechanical analysis can be done in qualitative and quantitatively.

**Kinematics:** The kinematics is that branch of biomechanics, which concerned with description of the movement of segments of the body without regard to the forces and cause due to which the movement occurred. Kinematics has two branches i.e. Linear kinematics and Angular kinematics.
**Linear Kinematics:** It deals with the kinematics of translation, or linear motion. When a body moves, all part of it travels exactly the same distance, in the same direction in the same time.

**Linear Distance:** The actual distance covered by a body or an object is the distance. In other words it is the total distance covered by a body or an object from starting position to final position.

**Linear Displacement:** The minimum distance between the initial position and the final position of a body in motion is called displacement.

**Linear Velocity:** It is the rate at which a body moves from one location to another in a given direction in respect to time. So it can be defined as rate of change of position (displacement) of a body with respect to time in a given direction.

**Linear Speed:** The speed of moving body is the rate at which the distance is covered by the body.

**Angular Kinematics:** It deals with the kinematics of rotation or angular motion. In angular kinematics every particle of the body moves in a circle and the centers of all these circles lay at the axis of rotation.

**Angular Distance:** The angle traversed by a rotating body is called angular distance. In other words, it is the angle between the initial and the final position measured following the path of rotation.
**Angular Displacement:** The maximum angle between the initial position and the final position of a body in rotation is called angular displacement. In other words, it is the smaller of the two angles between the initial and final position.

**Angular Speed:** The average angular speed of a rotating body is defined as the rate at which angular distance is covered.

**Angular Velocity:** The average angular velocity of a rotating body is defined as the rate at which angular displacement has occurred.

**Drag-flick:** The drag-flick is a variation of penalty corner and specialist scoring shot usually played as a set piece during penalty corners. The action involves a player crouching low down next to the ball and picking it up on the shaft of the hockey stick. The ball is then pushed along the ground whilst the stick is moving with a 'slinging' action. This serves to accelerate the ball, which is eventually released in a goal-wards direction, often raised.

**Technique:** Technique is defined as motor procedure for tackling a motor task. Motor procedure should be understood as a system of movement of body in a definite sequence. Many of these movements, however, may take place simultaneously.

**Tactics:** Tactics consist of tactical actions as well as other measures which are adopted before or during the competition for successful participation. Tactics is
theory of rules, possibilities, means and forms of successful formulation of competition activity in sports.

*Push-in Distance (meters)*: The linear distance from pusher to stopper.

*Push-in Ball Travel Time (seconds)*: The time which was consumed to reach the ball from pusher to stopper.

*Push-in Ball Velocity (km/h)*: The speed at which ball moves towards stopper from the pusher.

*Drag Distance (meters)*: The distance which was covered by the drag-flicker when he drags the ball prior to flick the ball into goal-words.

*Drag Speed (km/h)*: The speed at which the drag-flickers drag the ball along with the ground prior to flick the ball goal-words.

*Drag Time (seconds)*: The time spends by drag-flicker to drag the ball prior to flick the ball.

*Stance Width (meters)*: The maximum distance between right toe to left toe at the time of drag-flick.

*Stick Angle at Initial Ball Contact (degree)*: The angle of the stick in relation to the ground at the time when drag-flicker initiates the movement.

*Stick Angle While Dragging the Ball (degree)*: The angle of the stick in relation to the ground at the time of dragging the ball along the ground.

*Stick Angle at Release (degree)*: The angle of the stick in relation to the ground at the time of release of the ball from the stick.
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*Time Taken to Release the Ball (seconds):* The time consumed between initial touch to the release of the ball from the stick.

*Drag-flick Velocity (km/h):* The speed of drag-flick.

*Total Time Taken (seconds):* It was the time which starts at the point when pusher push the ball towards stopper and end when ball crosses the goal line (in case of converted penalty corners) or when ball trapped or stopped by any defender (in case of non-converted penalty corners).

**Delimitations**

Every research is limited in several ways. It has to be delimited in terms of population covered, sample selected and scope of available study area. Following were the delimitations of the present empirical analytical study:

i. The study was confined to the men’s international hockey matches played in the year 2010 only.

ii. Research was conducted on the male players of the Indian and other top five ranked foreign hockey teams.

iii. Only top five ranked foreign teams for the year 2010 were considered for the study based on the ranking of F.I.H. for 2010.

iv. The study was restricted to the analysis of 8 converted and 8 non-converted (a total of 16 penalty corners) of the Indian team.

v. The study was further restricted to the analysis of 8 converted and 8 non-converted (a total of 16 penalty corners) for each of the first five ranked foreign counterparts.

vi. This study was a two-dimensional biomechanical analysis.
Limitations

There are numerous limitations which are par from our control. There are following limitations of the present study.

i. The quality of the video footage of the men's international hockey matches considered as limitation of the study.
ii. The features of the motion analysis software used were the limitation of the study as it cannot be upgraded.
iii. The direction of wind during the course of data acquisition was also considered as the limitation of the study, as it can affect the rate of velocity.

Hypotheses

On the basis of previous research findings, literature reviewed, expert opinion and scholar's own understanding of the problem, it was hypothesized that, there would be no significant differences in the selected biomechanical variables of penalty corner execution of Indian team as compared to foreign counterparts. It was further hypothesized that, there would be no significant differences in the variables of converted and non-converted penalty corner executions of each team selected in this study.

Objectives of the Study

The prime goal of the study was the analysis of penalty corner execution of Indian team as compared to foreign teams. In order to realize the goals of the study following objectives were stated:
i. Efforts were made to compare world’s top five ranked field hockey team’s penalty corners executions with Indian team’s penalty corners executions and thereby formulate coaching recommendations specific to penalty corner execution.

ii. The other objective of the study was to compare the variables of converted penalty corners with the non-converted penalty corner’s variable of Indian team.

iii. To compare the variables of converted penalty corners with the non-converted penalty corner’s variable of Australian team.

iv. To compare the variables of converted penalty corners with the non-converted penalty corner’s variable of Dutch team.

v. To compare the variables of converted penalty corners with the non-converted penalty corner’s variable of German team.

vi. To compare the variables of converted penalty corners with the non-converted penalty corner’s variable of English team.

vii. To compare the variables of converted penalty corners with the non-converted penalty corner’s variable of Spanish team.

**Significances of the Study**

The inference drawn out of the biomechanical analysis of penalty corner of Indian team as compared to foreign counterparts in the field hockey would be beneficial in the following ways:

i. The findings of the study would evolve new measures for improving the goal scoring ability of Indian team via penalty corner.
ii. The findings of the study would provide necessary feedback to the players, coaches and experts of penalty corner regarding their existing methods of execution of penalty corner.

iii. The findings of the study would go a long way in capitalizing the chance of goal scoring of our team India at international competitions.

iv. The findings of the study would benefit the budding penalty corner experts who could be best groomed from very beginning of their learning process to develop a flawless motor habit by using the principles derived from the present analytical study.

v. The findings of the study would offer new choices, new set plays and offering more possibilities to convert a goal from penalty corner.

vi. The biomechanical analysis of various movements involved in the process of taking penalty corner would explore the short comings and strength in the movement variations of specific team which helps to understand and justify the appropriate movement execution and techniques.

vii. The outcomes of the present analytical study of penalty corner can be used as guideline to enable coaches and others to train and guide their teams and players to success.

viii. The analysis of the technical aspect of skill movement which is involve in the execution of penalty corner would help players to integrate the technical and tactical components of the sport and in so doing invigorate their needed sports skills.

ix. The analysis of technical aspect would offer hope to understand the need of technique level to be a penalty corner specialist, because the
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research would unfold the technical aspect of penalty corner experts in respect to the position.

x. The biomechanical analysis of penalty corner execution in field hockey would provide a strategic functional guide to the players as well coaches to achieve efficiency during penalty corner execution.

xi. The study would be provide a reliable functional biomechanical manual or guide for hockey players and coaches to assess the performance of any hockey team or player and draw a particular training programme for a hockey team or player regarding penalty corner execution.

xii. This study would equip the player as well as trainers and coaches to get the maximum advantage of mechanical aspects in the penalty corner drag-flick execution.

Methods and Materials

To work on the preceding hypotheses, along with Indian team only top five ranked overseas teams were taken as the subjects of the study. The top five ranked teams according to FIH ranking 2010 taken in this study were- Australia, Germany, Netherlands, England and Spain. A total of 96 penalty corners (16 for each team) were taken for analysis. The data were drawn from the Men’s Hockey World Cup 2010 and Commonwealth Games (Men) 2010, both tournaments were held at New Delhi, India. The data was obtained from the recorded video-clips of international matches during the men’s hockey world cup and commonwealth games 2010, held at New Delhi, India, recorded by the official analyst attached with the Indian team. In this study two software were used, one is for slicing of videos (i.e. PVC) and seconds one for analysis of the sliced clippings (i.e. Siliconcoach Pro7
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Biomechanically digitization of converted and non-converted penalty corner execution of top five ranked and Indian team was done by using Silicoancoach Pro7 motion analysis software. Each penalty corner clips were played one by one in the software and digitized with the help of its tools. The biomechanical parameters of the penalty corner execution (converted and non-converted both) which were analyzed with the help of motion analysis software were: push-in distance, push-in ball travel time, push-in ball velocity, drag distance, drag speed, drag time, stance width, stick angle at initial ball contact, stick angle while dragging the ball, stick angle at release, time taken to release the ball, drag-flick velocity and total time taken. The basic statistical analyses like mean, SD, MD were computed in the first phase of statistical analysis. In the second part the one way analysis of variance (ANOVA) was used to determine the differences among India and top five foreign counterparts. The t test was also applied to compare converted and non-converted penalty corners of each team individually. An alpha level of 0.05 was set to determine the statistical significant difference.

Results

The results of the study indicated that in the execution of converted penalty corners there were significant differences existed among all six teams (India, Australia, Netherlands, Germany, England, Spain) at 0.05 level of significance on the parameters of push-in distance, push-in ball travel time, push-in ball velocity, drag distance, drag speed, drag time, stance width, stick angle at initial ball contact phase, total time taken to release the ball, drag-flick velocity. Whereas no significant difference documented in the parameters of stick angle while dragging the ball, stick angle at release.
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phase and total time taken. For the non-converted penalty corner executions it was found from the results that there were significant differences existed among all six teams on the variables of push-in ball travel time, push-in ball velocity, drag distance, drag speed, drag time, stance width, stick angle at release, total time taken to release the ball and drag-flick velocity. However no significance differences existed among all selected teams on the variables of push-in distance, stick angle at initial ball contact, stick angle while dragging the ball and total time taken of the non-converted penalty corners.

There were significant differences found between converted and non-converted penalty corner set play of all teams in the variable of drag-flick velocity. For variable of push-in distance it was found that there were no significant differences found between converted and non-converted penalty corners of the all team's except Australian team. There were no significant differences found between converted and non-converted penalty corner execution of all team's variable push-in ball travel time, whereas significant difference was found for British team converted and non-converted penalty corner executions. There were no significant differences found between converted and non-converted penalty corner executions of Indian, German, Dutch and Spanish team's variable push-in ball velocity and significant difference was found for Australian and British teams only. No significant differences found between converted and non-converted penalty corner of all team's variable drag distance, and significant difference was found for Netherlands team. There were significant differences found of the Indian, German, Dutch and British team's variable stance width between converted and non-converted penalty corner executions, whereas no significant difference found for the Australian and Spanish in the converted and non-converted penalty corner executions.
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There were no significant differences found between converted and non-converted penalty corner executions of all team's variables drag speed, drag time, stick angle at ball contact, stick angle during dragging, stick angle at release, total time taken to ball release and total time taken.

Conclusions

The purpose of the study was to compare penalty corner execution of Indian team with their top five ranked foreign counterparts. Within the limits and limitations and on the basis of the results obtained following conclusions can be drawn:

Conclusions on Converted Penalty Corners

- In the converted penalty corners the push-in distance which Indian team covered was on an average 17.46 meters, which was less than Australian team's average distance (18.18 meters), and almost similar to the all other teams.

- The ball travel time to cover the distance from pusher to stopper in the converted penalty corners for Indian team was 1.08 seconds, which was less than German (1.27 seconds), Australian (1.18 seconds), Dutch (1.18 seconds) and Spanish (1.17 seconds) teams and more than British team (0.99 seconds).

- Indian team pushed the ball (from pusher to stopper) to stopper with an average velocity of 55.73 km/h in the converted penalty corners, while only British team pushed with the velocity (56.92 km/h) which was higher than Indian team, and other teams were slower in comparison with Indian team.
• The Indian team on an average dragged the ball prior to flick 2.44 meters in the converted penalty corners, while only Dutch team dragged the ball (2.50 meters) more than Indian team and remaining teams less than Indians. Germans team was the least who dragged only 1.91 meters.

• The speed of the drag (prior to flick) of the Indian team for converted penalty corners was 7.03 km/h which was almost similar to German team (7.05 km/h) only, Spanish team (8.22 km/h) was faster than Indian team, Australian team was the slowest amongst all teams who dragged with the velocity of 5.74 km/h.

• Indian team took on an average 0.74 seconds to drag the ball prior to flick in the converted penalty corners, while Australian (0.80 seconds) and Dutch (0.76 seconds) teams took more time than Indian team, British (0.69 seconds), German (0.45 seconds) and Spanish (0.40 seconds) were took less time in comparison with Indian team. Spanish team took almost half time in comparison with other teams and they were quick with the other teams.

• The stance width of Indian team was 1.56 meters wide and only Australian (1.68 meters), Dutch (1.59 meters) and German (1.57 meters) teams took a much wider stance in comparison with Indian team and Spanish (1.40 meters) and British (1.36 meters) were took a smaller stance width in the converted penalty corners.

• At the time of initial ball contact with the stick, the stick angel of Indian team was 58.25 degree which was almost similar to German (57.37 degree), Dutch (57.00 degree), British (56.00 degree) and Spanish (57.25 degree) team, while dissimilar to Australian (53.50
degree) team whose angle was lesser than Indian and other teams also in the converted penalty corners.

- While dragging the ball the stick angle of the Indian team was at an average angle of 39.00 degree, almost similar angles were found for all other teams also for converted penalty corners.

- As suggested from the results of the study on an average stick angle at release phase of Indian team was found at 19.37 degree, only Australian (21.62 degree) team was bent less than Indian team and remaining all teams bent at almost same degree of angle for converted penalty corners.

- To release the ball Indian team took 0.87 seconds in converted penalty corners, which was almost same to the Australian (0.91 seconds), Dutch (0.91 seconds), and British (0.81 seconds) teams but more than German (0.57 seconds) and Spanish (0.53 seconds) teams, it was also found that German and Spanish teams were quick to flick the ball when compared with Indian and other teams.

- As far as drag flick velocity is concerned, it was observed from the results that in the converted penalty corners Indian team on an average flicked the ball with the velocity of 113.66 km/h which was slower than German (118.17 km/h), Dutch (118.10 km/h) and Spanish (116.01 km/h) teams but faster than Australia (104.38 km/h) and British (102.36 km/h) teams.

- To finish a penalty corner Indian team took on an average 2.34 seconds and almost all other teams also consumed similar amount of time in the converted penalty corners.
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Conclusions on Non-converted Penalty Corners

- In non-converted penalty corners, distance covered by all six teams was almost same to the converted penalty corners.

- In the non-converted penalty corners it was found that Indian took on an average 1.10 seconds, which was less than German (1.20 meters), Australian (1.11 meters) and Dutch (1.11 meters) teams and more than Spanish (1.09 meters) and British (0.94 meters) teams.

- In the non-converted penalty corners the results were same as the converted penalty corners, that except British team (54.60 km/h) all teams were slower than Indian team (52.66 km/h) when the ball velocity (from pusher to stopper) take into account.

- In the non-converted penalty corners Indian drag distance was 2.34 meters while none of the other teams drag distance was found more than Indian team.

- In the non-converted penalty corner's variable drag speed, Spanish (7.05 km/h) and German (6.88 km/h) team were faster than Indian team (6.32 km/h) and other teams were slower than Indian team.

- On an average 0.72 seconds Indian team took to drag the ball in the non-converted penalty corners, which was almost similar time taken in the converted penalty corners by Indian team (0.74 seconds), other teams took lesser time to drag the ball when compared with Indian team.

- In the non-converted penalty corners Indians took 1.48 meters wide stance which was similar to Dutch team (1.40 meters) and lesser to Australian (1.53 meters) and German (1.50 meters) teams, and wider than Spanish (1.37 meters) and British (1.20 meters) teams.
• The score of the study also suggested that in the non-converted penalty corners the stick angle at initial ball contact of Indian team (57.75 degree) was less in comparison with German (61.00 degree), Dutch (59.62 degree), British (60.25 degree) and Spanish (60.25 degree) team.

• For non-converted penalty corners it was found that Indian team bent their stick (while dragging the ball) at an average angle of 36.62 degrees, while other teams also follow the same trend and bent their stick at almost the same angle.

• In the non-converted penalty corners the angel of the stick at release phase was lesser than to converted penalty corners of Indian team, but other team’s angle were same as to converted penalty corners.

• Pertaining to the results it was found that in the non-converted penalty corners except German and Spanish team all teams were consumed same amount of time to release the ball.

• In the non-converted penalty corners the ball velocity of all teams were found less than converted penalty corners and it was one of the major causes for unsuccessful penalty corner execution.

• All six teams investigated showed that, the non-converted penalty corners also finished in the same time as converted penalty corners.

Conclusions on Converted Penalty Corners v/s Non-converted Penalty Corners

• There were no significant differences found between converted and non-converted penalty corners of the all team’s except Australian team variable of push-in distance.
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- There were no significant differences found between converted and non-converted penalty corner execution of all team's variable push-in ball travel time, and significant difference was found between converted and non-converted penalty corner execution of British team's variable ball travel time.

- There were no significant differences found between converted and non-converted penalty corner execution of Indian, German, Dutch and Spanish team's variable push-in ball velocity and significant differences were found for Australian and British teams.

- There were no significant differences found between converted and non-converted penalty corner execution of all team's variable drag distance, and a significant difference was found between converted and non-converted penalty corner execution of Netherlands team's variable drag distance.

- There were no significant differences documented between converted and non-converted penalty corner set play of all team's variable drag speed.

- There were no significant differences found between converted and non-converted penalty corner set play of all team's variable drag time.

- There were significant differences found in the Indian, German, Dutch and British team's variable stance width between converted and non-converted penalty corner executions. Whereas no significant difference found for the Australian and Spanish team.
- There were no significant differences reported between converted and non-converted penalty corner set play of all team’s variable stick angle at initial ball contact.

- There were no significant differences found for all team’s variable stick angle during dragging between converted and non-converted penalty corner execution.

- There were no significant differences observed between converted and non-converted penalty corner execution for all team’s variable stick angle at release.

- There were no significant differences documented between converted and non-converted penalty corner execution for all team’s variable total time taken to ball release.

- There were significant differences found between converted and non-converted penalty corner set play of all team’s drag-flick velocity.

- There were no significant differences found for all team’s variable total time taken between converted and non-converted penalty corner executions.

**Suggestions**

Pertaining to the results of this experimental investigation following suggestion is forwarded:

- Coaches and trainer should emphasis on push-in ball velocity during training sessions as this gives drag-flicker an extra amount of time to adjust himself to perform better during drag-flick execution.
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- As results suggested that drag-distance and drag-speed prior to drag-flick should be maximized. This will provide an extra edge to drag-flicker to generate an extra amount of velocity into ball, hence it is suggested that coaches and trainer should work on this factor and train their players how can they maximize their drag-distance and speed.

- Coaches and trainer should encourage penalty corner specialist to use a large stance width, during penalty corner execution as it helps in maximizing the drag-distance which resulted in generating momentum into the ball.

- It is suggested that coaches and trainer should train their penalty corner specialist bent their body as low as they can while dragging the ball prior the flick. This will help them to gain elevation in the ball.

- Coaches and trainer should encourage penalty corner specialist to release the ball as quickly as possible to give a dodge to opponent goal-keeper.

- During the course of training of penalty corner set play push-in distance and time could be neglected by the coaches or trainer, but the accuracy and proper trapping of the ball should be emphasized.

Recommendations

The present study was confined to study the associated and significant biomechanical variables of penalty corner executions only. Since researches and explorations are not the end in itself, but merely open the way for future investigations. Similarly, the present work is not the end in
this area. In fact, all the variables can never be studied in a single research. The results of the present investigation led to certain possibilities for further researches.

i. Since it is a 2D (two dimensional) biomechanical analysis, therefore a similar 3D (three dimensional) analysis with the same variables may be conducted which may give further insight to the penalty corner specialists.

ii. Larger samples provide better results, the present research work was confined to only 8 converted and 8 non-converted penalty corner executions for each team. Thus it cannot claim for its comprehensiveness. Future researches may be conducted on even much larger samples. The results may provide greater insight for hockey players and their coaches and sports scientist.

iii. It is suggested that further studies in this area may compare male and female hockey players.

iv. For future research, a similar study may be conducted in both kinetics and kinematics variable.

v. This study is confined only top five ranked hockey teams, thus a similar study may be conducted with all participating teams of the world.

vi. A comparative study with the same variable may be conducted on leading continental teams.

vii. A comparative study may be conducted within the continental teams.

viii. A similar study may be conducted with the same parameters on female top ranked teams.
ix. Same study may be duplicated on the junior teams, to know the potential of budding penalty corner experts of drag-flick.

x. In order to draw more authentic predictions, the physiological and psychological parameters of the hockey players must be studied along with biomechanical parameters for future research.

xi. It is believed that with further development, a useful training aid could be developed. Also, new insights into the mechanics of the drag flick action may be revealed. Future applications would include skill-based studies of technique, differences in the timing of force delivery, differences in the amount and timing of the displacement along the shaft, complementary measurements of ball speed after release, learning-based studies to explore the rate of skill development in novices.

Considering the above mentioned recommendations it may be submitted that as a single researcher one may not able to take-up such research project independently, because such type of researches required specific equipments and other lab facilities, hence premier institutions such as Sports Authority of India (SAI), International Hockey Federation (IIHF), Hockey India (HI), Sports Ministry, University Grants Commission (UGC), Sports Academies, Central Universities and Sports Excellencies etc. must take initiative to undertake long term research projects on the such topic to determine the predictors of sports performance instead of merely stressing on any one of few constructs of performance. Hence, a holistic and interdisciplinary approach by the institutions conducting higher research may be adopted.