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Summary

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).

Among all sports field hockey occupies a significant place in India and regarded as a national game of our country (Sanyal, 1972). Being a national game of our county, obviously field hockey 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. 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 recently concluded Olympics shows Indian lost their supremacy in the world of hockey (Ganesh, 2005). The experts in the field believed that there have been numerous potential factors which are responsible to this decline in our performance includes 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 (Copel, James & Bartlell, 2012a; Chapman, Newton & McGuigan, 2009; Astorino, Tam, Rietschel, Johnson & Freedman, 2004).
Despite of the declined performance of our teams in premier tournaments, Indian team are still being considered one of the world’s best teams. With the arrival of Astroturf the nature and demand of the game has totally changed (Whitaker, 1992). As far as the techno-tactical aspect of hockey is considered numerous significant techniques and skills have been emerged at present (Pearsall, Turcotte & Murphy, 2000). In today’s game of hockey merely techno-tactical soundness is not enough (Hussain, 2012). There is need to learn as well as develop all those factors on which present day performance in hockey lies (O’Donoghue, 2008; Wiseman & Wiseman, 2003).

Keeping in view the demand of the today’s game a few new systems and techniques of play have also been developed (Pearsall, Montgomery, Rothsching & Turcotte, 1999). Beside these systems numerous set plays including taking and defending penalty corner which play a decisive role in winning major competitions. Thus, the penalty corner is considered to be the main weapon for getting goals during the course of competitions (Hussain, Ahmed & Khan, 2012; Laird & Sutherland, 2003). Most of the major hockey playing countries such as Australia, Netherlands, Germany, South Korea, Spain, England, Pakistan, Malaysia and Argentina and at present India also, have been assigning special weightage to train the experts of penalty corner who could convert every chance of penalty corner in to a goal.

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 (Meulmana, Berger, Zande, Kok, Ottevanger & Cruqu, 2012; DeSubijana, Gomez, Martin-Casado & Navarro, 2012). 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. 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. 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. To work on this the researcher 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.

To work on the preceding hypothesis, 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. Silicoancoach Pro7 software). 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.

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 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. 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.
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- 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.

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 (120
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.
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- 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 angle 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.

- 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.
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- 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.

- 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.
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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.
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.

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 (IHF), 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.