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PENALTY STROKE IN FIELD HOCKEY AT FOUR DIFFERENT CORNERS OF GOALPOST: A KINEMATICAL ANALYSIS

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ABSTRACT

The purpose of this study was to analyze the penalty stroke when it is executed with 45 degree stance. For the purpose of the study 6 intervarsity level male hockey players who represented University of Lucknow, Lucknow, India were selected as the subjects. The mean age, height and body weight of the selected subjects were 20 yrs, 169.67 cm and 59.5 kg, respectively. One high speed camcorder was used to capture the execution of penalty stroke. The camcorder was placed at 10 meters away from the penalty spot on the saggital plane of the subjects and perpendicular to the backline. The height of the camcorder was adjusted as required 1.5 meters from the ground. At each critical corner of the goal post i.e. right top corner (RTC), left top corner (LTC), right ground corner (RGC) and left ground corner (LGC), specially designed (2×2 feet) targets were placed to determine the ball accuracy. After experimental setup the subjects were asked to perform 3 penalty strokes each for all four corners of the goalpost with 45 degree stance (DS). Their movements during the execution were recorded in the camcorder. After recording all the video footages were downloaded into personal computer and subjected to biomechanical analysis. The analysis was performed with the help of Silicon Coach Pro7 motion analysis software. The ball velocity, acceleration, accuracy, stride-length contact-length and contact-time were taken as variables. The one way analysis of variance was computed to know the difference among all four corners of the goalpost. The results of the study indicated that there were no significant difference existed among all four corners of goal-post in the all selected variables when penalty stroke was executed with 45 DS.
Keywords: *Field hockey, penalty stroke, kinematics, 45 degree stance.*

1. INTRODUCTION

At the highest level hockey is a fast-moving highly skilled sport with players using fast moves, quick accurate passing, and hard hits, in attempts to keep possession and move the ball towards the opponents' goal (Hussain, Mohammad, Khan, & Bari, 2011). Collisions are common while physically tackling and otherwise obstructing players is not permitted, and the speed at which the ball travels along the ground and sometimes through the air. Obstruction typically occurs in three circumstances- i) when a defender comes between the player in possession without first performing a legitimate tackle; ii) when a defender's stick comes between the attacker's stick and the ball or makes contact with the attacker's stick, and iii) also when (usually deliberately) blocking the opposition's passage to the ball (called third party obstruction). When obstruction is done by an extreme foul means penalty stroke is awarded to the opponent team (International Hockey Federation, 2013).

In recent years, the penalty stroke has gained importance as a vital part of the game as goal scoring opportunity (Hussain, Mohammad, & Khan, 2011). Scoring a goal from a penalty stroke depends on various factors. The most important is the deceiving qualities of the players. Further penalty stroke taking stance is also plays a significant role (Hussain, Paul, Mohammad, & Nongogo, 2012). The players select their own stance position and coordination pattern via a process of self-organization to find a solution within the

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context of constrains (Bretigny, Seifert, Leory, & Chollet, 2008). The ability to quantify the coordination patterns or coupling relationship between movements onset to release is extremely useful in the execution of penalty stroke.

In the game of hockey every team has one or two penalty stroke specialists. As penalty stroke become extremely important aspect of field hockey because it gives a clear chance to convert it into a goal. Conversion of a goal via penalty stroke is highly technical as well as skillful aspect. In a goalpost which is guarded by a goal-keeper it is difficult for penalty stroke specialist/player to score. Defeating the goal-keeper are demands quick deceiving qualities of the player alongwith speed and movement accuracy. Only four extreme corners of the goalpost are vacant when a penalty stroke is set into motion. Thus it is important for the striker to use proper skill and put the ball into the vacant space of the goalpost to score a goal. As seen at the international matches every specialist uses their own specific stances to execute penalty stroke. Regardless of a particular style or school of thought for sports techniques, from a mechanics standpoint, the body can only move optimally in one way (Sibella, Crivellini, & Galli, 2004). This is due to the alignment of bones, the direction of muscle fibers and the designated contractile properties of those fibers (Anders, & Myers, 2008).

However, there is still a lack of scientific research done on penalty stroke execution in field hockey (Willmott & Dapena, 2005; Kerr & Ness, 2006; Bretigny, Seifert, Leory & Chollet, 2008; Yusoff, Hasan & Wilson, 2008; Willmott & Dapena, 2008). It will be of great interest for sports scientists or hockey coaches to study the mechanics involved in the penalty stroke execution. This would provide information that will enhance the performance of penalty stroke specialists. Thus, the present study was undertaken to analyze the biomechanical factors of 45 DS penalty stroke taking stances and observe the mechanical efficiency of this particular stance.

2. METHODS AND MATERIALS

2.1 Subjects

Six intervarsity level male hockey players who represented University of Lucknow, Lucknow, India were selected as the subjects of this study. The mean age, height and body weight of the selected subjects were 20 ± 0.89 years, 169.67 ± 5.68 cm and 59.5 ± 4.63 kg, respectively.

2.3 Tools

The experimental apparatus used in this research work were camcorder (Canon Legria HF S10) with tripod, motion analysis software (Siliconcoach Pro7) measuring tap, four targets (2×2 feet to determine the accuracy) marked with a scale, hockey sticks and balls.

2.4 Experimental Setup

One high speed camcorder was used to capture the execution of penalty stroke. The camcorder was placed at 10 meters away from the penalty spot on the sagittal plane of the subjects and perpendicular to the back line (Figure 1). The height of the camcorder was adjusted as required 1.5 meters from the ground. At each critical corner of the goalpost i.e. right top corner (RTC), left top corner (LTC), right ground corner (RGC) and left ground corner (LGC), specially designed (2×2 feet marked scale) targets were placed to determine the ball accuracy (Figure 2).

2.5 Data Acquisition

After a specific warm-up subjects were asked to execute 3 penalty strokes, each for all four corners of the goalpost with 45 DS (Figure 3). Their movements during the penalty stroke execution were recorded in the camcorder. After recording all the video footages were downloaded into personal computer and subjected to biomechanical analysis.

2.6 Data Analysis

The analysis was performed with the help of Siliconcoach Pro7 motion analysis software. The ball velocity, acceleration, accuracy, stride length, contact time, and contact length were taken as variables and digitized with the help of motion analysis software.

For the calculation of accuracy in the 2 feet square target 8 vertical strips 3 inches in the width were drawn. When subjects strike the inner most strip they were considered as 12.5% accurate and when they strike next to the inner most strip 25% accuracy were considered and so on, if subjects misses the target the accuracy recorded as 0%.

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2.7 Statistical Analysis

Statistical analysis was carried out by using SPSS v.16 software. The acquired data on the selected biomechanical variables were sequentially arranged in a tabular format and subjected to the one way analysis of variance (ANOVA). The alpha level of significance was set at $p < 0.05$.

Figure 1: **Experimental setup; including the subject and camcorder position**

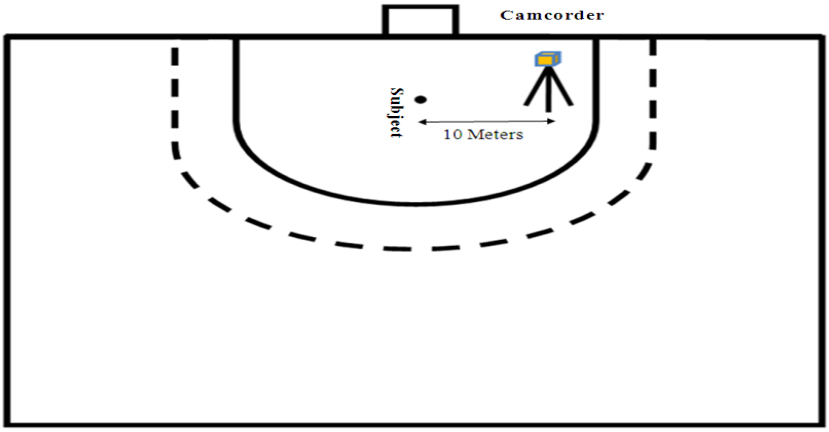


Figure 2: Showing targets at goalpost

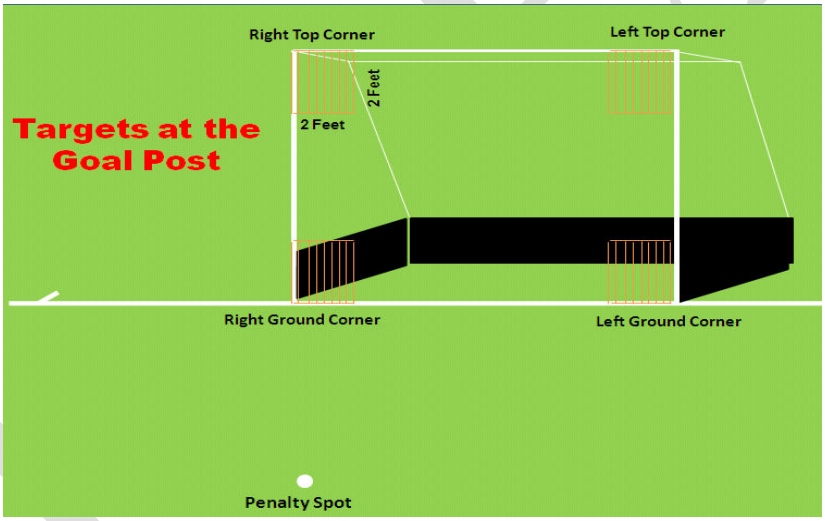
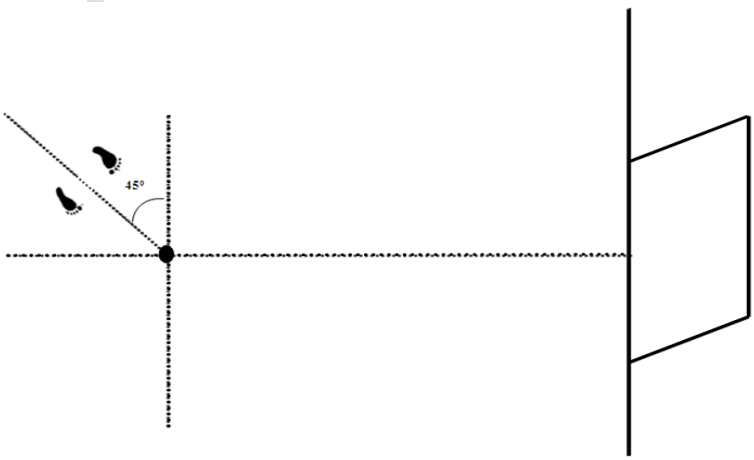


Figure 3: Overhead view showing 45 Degree Stance Position for penalty stroke execution



3. RESULTS

The result of the study is presented in the following Tables.

Table 1: Indicating descriptive statistics of the kinematical variables of penalty stroke execution with 45 DS of all four critical corners of goalpost.

Variables		RTC	RGC	LTC	LGC
Accuracy (%)	M (± SD)	50.00 ± 23.72	33.33 ± 12.91	47.92 ± 30.02	47.92 ± 14.61
	Min	25	12.5	12.5	37.5
	Max	75	50	75	75
Acceleration (m/s^2)	M ± SD	18.22 ± 4.96	22.22 ± 12.86	17.34 ± 3.44	19.92 ± 4.51
	Min	12.16	12.14	14.33	11.6
	Max	27.25	47	23.6	24.8
Velocity (m/s)	M ± SD	25.42 ± 6.42	27.40 ± 2.74	30.35 ± 5.35	33.60 ± 6.14
	Min	12.38	22.41	20.49	21.64
	Max	28.58	30.71	35.2	38.81
Stride Length (m)	M ± SD	1.11 ± 0.11	1.17 ± 0.15	1.26 ± 0.18	1.28 ± 0.13
	Min	0.95	0.99	1.05	1.13
	Max	1.25	1.33	1.6	1.5
Contact Time (s)	M ± SD	0.06 ± 0.01	0.05 ± 0.02	0.06 ± 0.02	0.06 ± 0.02
	Min	0.04	0.02	0.04	0.04
	Max	0.06	0.08	0.09	0.1
Contact Length (m)	M ± SD	0.97 ± 0.13	0.98 ± 0.13	1.08 ± 0.20	1.13 ± 0.25
	Min	0.73	0.85	0.86	0.85
	Max	1.09	1.21	1.4	1.56

Abbreviations: RTC, Right top corner; RGC, Right ground corner; LTC, Left top corner; LGC, Left ground corner.

Table 2: One way analysis of variance (ANOVA) of the variable "Accuracy"

Source of Variance	Sum of Squares	*df*	Mean Square	*F*
Between Groups	1067.70	3	355.90	0.77
Within Groups	9218.75	20	460.93	
Total	10286.45	23		

Tabulated $F_{0.05}(3,20)= 3.09$

It has been depicted from the readings of the above Table 2 that calculated *F* value (0.772) was found to be insignificant on the variable of accuracy. It indicates that there was no significant differences exist among RTC, RGC, LTC and LGC when penalty stroke was executed with 45 DS.

Table 3: One way analysis of variance (ANOVA) of the variable "Acceleration"

Source of Variance	Sum of Squares	*df*	Mean Square	*F*
Between Groups	83.255	3	27.752	0.500
Within Groups	1111.104	20	55.555	
Total	1194.359	23		

Tabulated $F_{0.05}(3,20)= 3.098$

The readings of the above Table 3 indicated that calculated *F* value (0.500) was found to be insignificant on the variable of acceleration. It indicates that there was no significant differences exist among RTC, RGC, LTC and LGC when penalty stroke was executed with 45 DS.

Table 4: One way analysis of variance (ANOVA) of the variable "Ball Velocity"

Source of Variance	Sum of Squares	*df*	Mean Square	*F*
Between Groups	229.464	3	76.488	2.661
Within Groups	574.960	20	28.748	
Total	804.423	23		

Tabulated $F_{0.05}(3,20)= 3.098$

It is vivid from the above Table 4 that calculated *F* value (2.661) was found to be insignificant on the variable of ball velocity. It indicates that there was no significant differences exist among RTC, RGC, LTC and LGC when penalty stroke was executed with 45 DS.

Table 5: One way analysis of variance (ANOVA) of the variable "Stride Length"

Source of Variance	Sum of Squares	*df*	Mean Square	*F*
Between Groups	.114	3	.038	1.809
Within Groups	.421	20	.021	
Total	.535	23		

Tabulated $F_{0.05}(3,20)= 3.09$

Table 5 indicated that calculated *F* value (1.809) was found to be insignificant on the variable of stride length. It indicates that there was no significant differences exist among RTC, RGC, LTC and LGC when penalty stroke was executed with 45 DS.

Table 6: One way analysis of variance (ANOVA) of the variable "Contact Time"

Source of Variance	Sum of Squares	*df*	Mean Square	*F*
Between Groups	0.000	3	0.000	0.288
Within Groups	0.007	20	0.000	
Total	0.007	23		

Tabulated $F_{0.05}(3,20)= 3.098$

It is documented in the above cited Table 6 that calculated *F* value (3.288) was found to be insignificant on the variable of contact time. It indicates that there was no significant differences exist among RTC, RGC, LTC and LGC when penalty stroke was executed with 45 DS.

Table 7: One way analysis of variance (ANOVA) of the variable "Contact Length"

Source of Variance	Sum of Squares	*df*	Mean Square	*F*
Between Groups	0.110	3	0.037	1.075
Within Groups	0.681	20	0.034	
Total	0.791	23		

Tabulated $F_{0.05}(3,20)= 3.09$

The values of the above cited Table 7 indicated that calculated *F* value (1.075) was found to be insignificant on the variable of contact length. It indicates that there was no significant differences exist among RTC, RGC, LTC and LGC when penalty stroke is executed with 45 DS.

Figure 4: Illustration showing mean values of accuracy at all four corners

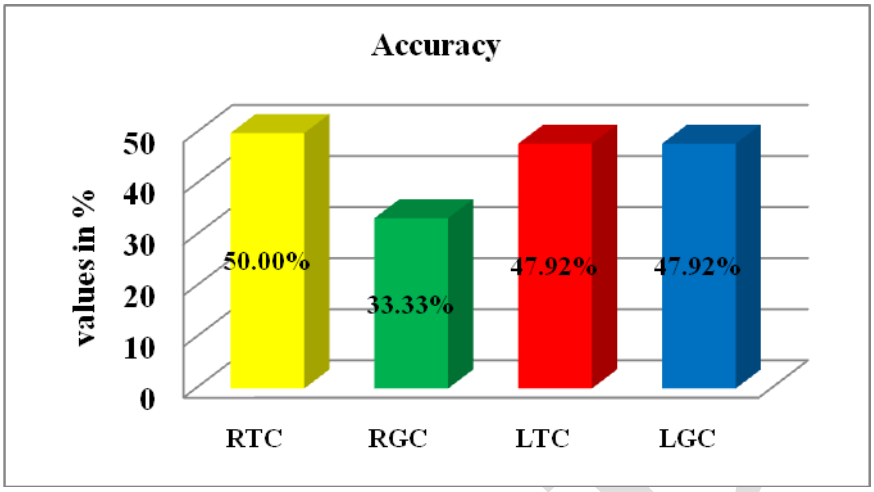


Figure 5: **Illustration showing mean values of acceleration at all four corners**

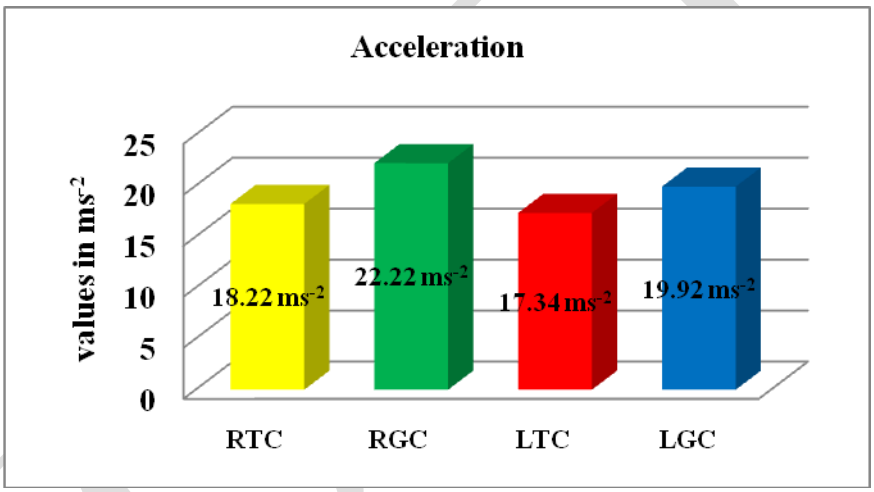


Figure 6: **Illustration showing mean values of velocity at all four corners**

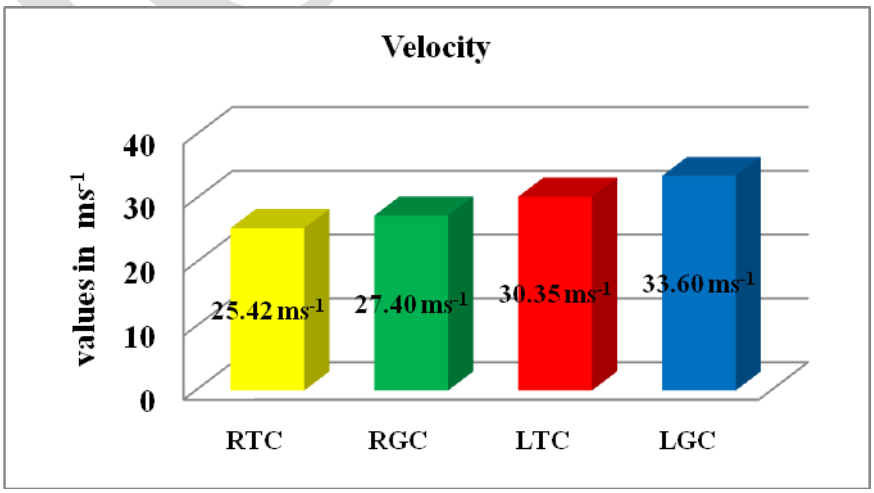


Figure 7: **Illustration showing mean values of stride length at all four corners**

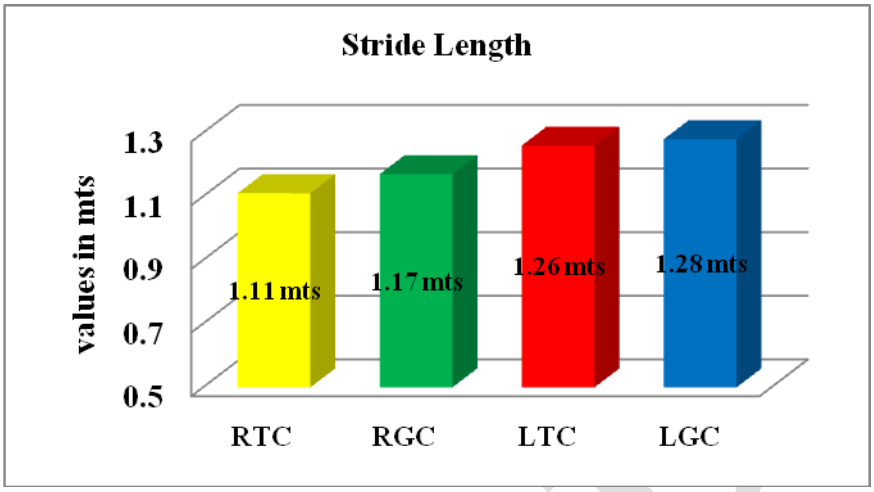


Figure 8: Illustration showing mean values of contact time at all four corners

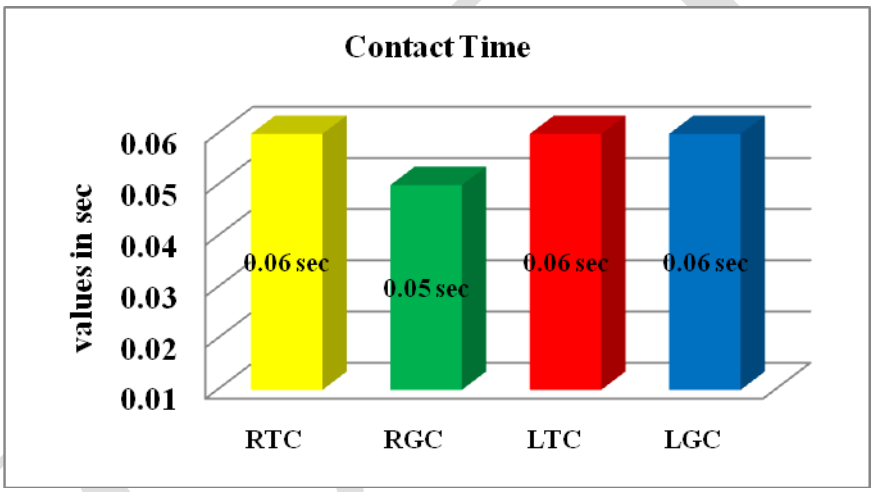
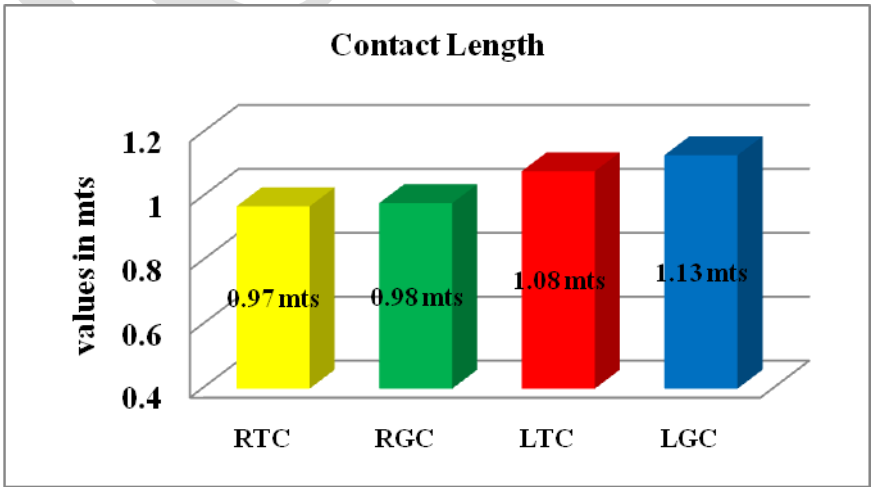


Figure 9: **Illustration showing mean values of contact length at all four corners**



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4. DISCUSSION

From the results it is documented that on RTC subjects gained maximum accuracy (50 %) whereas at RGC they scored 33.33 % which was less than RTC the reason may be that the velocity (27.40 m/s) is more than from the RTC (25.42). Critical evaluation of Table 1 documented that at left top and ground corner both have similar score on the variable of accuracy that may be due to the other variables have almost similar scores as stride length and contact time have similar score but when we talk about acceleration, velocity and stride length we inferred that RGC have higher score compared than LTC.

Examination of the results shown that the stride length, contact length and contact time are inter-dependent. The increase in stride length increased the contact time between the stick and the ball (Hussain, Paul, Mohammad, & Nongogo, 2012). The comparisons of means showed maximum stride length during penalty stroke execution at LGC at 45 DS. It was also observed that the extension of contact length and time between the stick and ball increased the velocity of the ball.

5. CONCLUSIONS

It was found in this study that there were no statistical significant difference existed among all four critical corners of goalpost. But, on the other hand following conclusions might be drawn:

- Form the accuracy point of view RTC is better option for penalty stroke specialist.
- Acceleration was reported higher at RGC, when acceleration is considered then RGC will be a good option for penalty stroke specialist.
- Maximum velocity was achieved at LGC, therefore from velocity point of it is good that penalty stroke specialist targets' this corner.
- LGC is the corner which is more appropriate for the penalty stroke specialist when stride length, contact time and contact length were taken into account.
- At 45 DS position of penalty stroke execution left side of the goal post is better option for the striker due to the factor that at this side subjects gets maximum freedom of movement which is evidenced from the results of this study.

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