Identifying Vulnerable Zones of the Goal during Penalty Kicks in Soccer Goalkeeping

Identificación de zonas vulnerables de la portería durante los tiros penales en el portero de fútbol

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Abstract

Background: In association football (Soccer), a penalty kick holds immense importance as one decisive kick can determine the outcome of years of hard work. Objective: The study aims to examine the frequency and success rate of penalty shootouts executed by Bangladeshi male footballers in various zones of the goal to categorize zone-specific vulnerability, strength, and frequency. Materials and Methods: Male sixty-two (n=62) field players and thirty-two (n=32) goalkeepers aged 15-30 were selected for the study. The goal was divided into 12 zones for study. A camera (GoPro 11) was placed outside the penalty area. Visual and video analysis with Kinovia motion analysis software was conducted simultaneously. Percentage and Chi-square tests were employed for statistical analysis. Results: The results show the highest goal-scoring percentages by zone in the following sequence: 1 (100%), 4 (94%), 3 (82%), 2 (64%), 12 (54%), 9 (52%), 5 (51%), 8 (50%), 6 (29%), 10 (18%), 11 (15%), and 7 (13%). In terms of targeted kick percentages, the order by zone from highest to lowest is as follows: 12 (20%), 9 (19%), 5 (13%), 8 (12%), 10 (12%), 4 (6%), 6 (5%), 7 (5%), 3 (4%), 2 (4%), 11 (4%), and 1 (3%). Pearson's Chi-square value is 59.234 with df = 11, and p = .000, indicating a statistically significant association between the zones in goal and the outcomes (goal or save). Conclusions: Most kicks target the lower side of the goalposts, with scoring chances increasing when kicked farther and higher, revealing different vulnerabilities across different areas in the goal.

Keywords

Association football; penalty shootouts; goalkeeping; goal distribution; zone-specific analysis.

Resumen

Antecedentes: En el fútbol, un tiro penal tiene una importancia inmensa, ya que un tiro decisivo puede determinar el resultado de años de arduo trabajo. Objetivo: El estudio busca examinar la frecuencia y la tasa de éxito de las tandas de penaltis ejecutadas por futbolistas bangladesíes en varias zonas de la portería para categorizar la vulnerabilidad, la fuerza y la frecuencia específicas de cada zona. Materiales y métodos: Se seleccionaron sesenta y dos (n=62) jugadores de campo y treinta y dos (n=32) porteros de entre 15 y 30 años para el estudio. La portería se dividió en 12 zonas para el estudio. Se colocó una cámara (GoPro 11) fuera del área penal. Se realizó simultáneamente un análisis visual y de video con el software de análisis de movimiento Kinovia. Se emplearon pruebas de porcentaje y chi-cuadrado para el análisis estadístico. Resultados: Los resultados muestran los porcentajes más altos de anotación por zona en la siguiente secuencia: 1 (100%), 4 (94%), 3 (82%), 2 (64%), 12 (54%), 9 (52%), 5 (51%), 8 (50%), 6 (29%), 10 (18%), 11 (15%) y 7 (13%). En términos de porcentajes de tiro dirigido, el orden por zona de mayor a menor es el siguiente: 12 (20%), 9 (19%), 5 (13%), 8 (12%), 10 (12%), 4 (6%), 6 (5%), 7 (5%), 3 (4%), 2 (4%), 11 (4%) y 1 (3%). El valor de Chi-cuadrado de Pearson es 59.234 con gl = 11 y p = .000, lo que indica una asociación estadísticamente significativa entre las zonas en portería y los resultados (gol o parada). Conclusiones: La mayoría de los tiros tienen como objetivo la parte inferior de los postes de la portería, y las posibilidades de gol aumentan cuando se patean más lejos y más alto, lo que revela diferentes vulnerabilidades en distintas áreas del arco.

Palabras clave

Fútbol asociación; tandas de penaltis; porterías; distribución de goles; análisis zonal.

Introduction

Since 1978, 16.3% of FIFA World Cup Football elimination matches have been decided by penalties, in 2022, this figure rose to 27.78% (Tijms, 2024), emphasizing the increasing significance of penalties in the outcome of competitions. Since the 1986 FIFA Men's World Cup at knockout stages, 20% of matches have been decided by penalty shootouts, besides, men and women together in the history of FIFA World Cups scored 261 goals on 370 attempts bringing about a 70.54% success rate (Cohen, 2022). Only in the 2022 FIFA World Cup, during regular and extra time 23 penalty kicks were awarded, and 17 kicks converted into goal which means the success rate was 73.91% (Evans, 2022). As of now, 22 FIFA World Cup tournaments have taken place where the first one was held in 1930 and the last one in 2022. Though the penalty shootout law was introduced in the year 1978 FIFA World Cup in Argentina (Murray, 1999), it came into practice in the 1982 World Cup in Spain in a match between West Germany and France (Rinke & Schiller, 2014). Since 1978 total of 12 FIFA Men's World Cups have been staged in which 3 final matches were decided by penalty shootouts in 1994, 2006, and 2022 which means 25% of final matches were decided in this way (Nag, 2022). The world has witnessed 172 goals out of 64 matches in 2022 where 17 goals came from penalty kicks which shows 9.88% of goals came from penalty kicks (Nalwala, 2022). Besides, in the 2018 FIFA World Cup, during regular and extra time 29 penalty kicks were awarded of which 22 scored and the conversion rate stands at 75.86% (Göral, 2019). All these statistics evidence the importance of penalty kicks and penalty shootouts in the game of Football to win a match. Penalty kicks bear immense strategic importance for a match (Okilanda et al., 2024). The only difference between a penalty kick and a penalty shootout is that a penalty is awarded during the game due to a foul inside the penalty area, whereas a shootout is called if tied at the end of a match at the knock-out round. This kick is taken from the penalty sport 12 years away from the middle of the goal line of the goalposts (IFAB, 2024). The challenge for the kickers is to place the ball into the 192 square feet of the goal whereas the challenge for the goalkeeper is preventing the ball from entering into the same area. A penalty kick or shootout is a highly exciting part of a football match for all spectators, players, and team management.

Effectiveness and understanding of game theory have been observed in the goalkeepers and kickers in penalty kicks when studying dividing the goal into various zones in soccer (Chiappori et al., 2002). There are weak and strong zones at the post to face a penalty kick for the goalkeepers as found while it was studied dividing into different zones (Bar-Eli & Azar, 2009). Professional soccer players can manage their performance in penalty kicks or shootouts at the toughest and furthest zones of the goal (Dohmen, 2008). Field players took penalty kicks four times as often in the lower zones than in the upper zones while the goal was divided into six zones for the study (Navia et al., 2019). In the 2022 World Cup, just over a quarter of elimination matches were decided by penalty shootouts, with nearly three-quarters conversion rate for penalties that stressed their crucial role and persistently higher success rates in football. Besides, systematic training with a satisfactory level of age-appropriate learning opportunities is essential for improving football skills (Ünlü et al., 2024). Moreover, the quantitative approach in football coaching holds enormous importance (D'Isanto et al., 2022; Kostiukevych et al., 2020). Based on preceding studies, it is evident that dividing the goal into different zones discloses strategic insights for both kickers and goalkeepers emphasizing the significance of zone-specific tactics during penalty kicks. A thorough literature review shows that no research has yet been conducted on Bangladeshi football players to find zone-specific vulnerability and frequency of penalty shots during penalty kicks or shootouts. It is not clear, how Bangladeshi football players perform penalty kicks regarding zone-specific frequency and success rate when the goal is divided into 12 zones. It is hypothesized that there is no statistically significant difference in vulnerability across various zones in soccer goal in terms of frequency of penalty kicks and rate of goal scoring. The study aims to examine the frequency and success rate of penalty kicks executed by Bangladeshi male football players in various zones of the goal to categorize zone-specific vulnerability, strength, and frequency.

Method

Participants

This study selected a total of 93 male football players comprising sixty-two (n=62) field players and thirty-one (n=31) goalkeepers from 28 out of 64 districts in Bangladesh. Their ages range from 15-30 years with a mean age of 27 years for Goalkeepers (GK) and 26 years for field players (FP). Goalkeepers' mean height, weight, body mass index (BMI), and training age were 1.73 m, 67 Kg, BMI 22.38, and 12.8 years respectively. The sample includes Goalkeepers from various levels- 3 from Bangladesh Premier League (BPL), 15 from Bangladesh Champions League (BCL), 9 from Dhaka 1st Division, and 4 from 2nd Division League. On the other hand, Field Players' mean height, weight, BMI, and training age were 1.69 m, 64 Kg, BMI 22.36, and 11 years respectively. Field Players represent a range of levels- 1 from National Team Member, 3 from BPL, 25 from BCL, 18 from Dhaka 1st Division, 6 from Dhaka 2nd Division league, and 9 from District 1st Division League. All of them come from six out of eight Divisions (Administrative Divisions) in Bangladesh. All the participants participated voluntarily in the study and they were free from any major injury in the six months preceding the data collection date.

Inclusion Criterion

In the study, all the players (Goalkeepers and Outfield Players) had the right side stronger, meaning the goalkeepers' right hand and outfield players' right leg were stronger than their corresponding left limb.
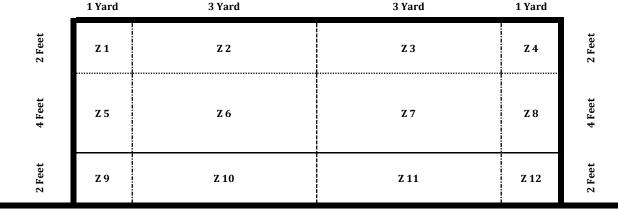
Assessment

The Data collected for the study included whether a penalty kick was a save by the goalkeeper or converted to a goal and the targeted zone of the shot. That means save, goal, and zone were the three parameters considered as data in the study. When any penalty shot hit the goalpost or crossbar and then entered into the goal, that kick was considered for the corresponding zone of the goal.

Study design

A cross-sectional study was designed using a random sampling technique. The goal was divided into 12 zones by flexible and colorful ropes. Three vertical ropes were anchored by attaching one side to the crossbar of the goal and the other end with the ground just behind the goal line. Two of these vertical ropes were fixed at 1 yard inside of each end of the goal and the third rope was placed in the middle of the goal. Conversely, 2 horizontal ropes' ends were fixed with two poles of the goal, one rope was fixed 2 feet above the ground and another 2 feet below the crossbar. Following the attachment, ropes were tightly bound to prevent movement where these intersected one another. Zonal numbers were given from left to right of the penalty kicker for the convenience of the study, as follows: Upper Row 1, 2, 3, and 4; Middle Row 5, 6, 7, and 8; and Bottom Row 9, 10, 11, and 12 [Figure 1]. Penalty kicks were taken following the standard law of the game. A kick was deemed valid only if the ball either remained in the goal area or hit any part of the goal, regardless of whether it subsequently reached the back of the net or was stopped by the goalkeeper. Each field player was allotted not more than 10 kicks, with 2 shots to each goalkeeper. In addition, each goalkeeper faced 10 kicks from 5 different field players. The researchers investigated how many kicks target each zone in the goal and what percentage of kicks converted into the goal at which zone. Additionally, the association between goals or saves and zones was examined.

Figure 1. Zonal divisions of the goal

Source: Chanda et al. (2025).

Instrument setting and recording

GoPro-11 a high-performance camera was placed just outside and at the middle of the penalty arc, where an imaginary perpendicular line extending from the middle of the goal line intersects the penalty sport. The camera was set at the height of 6′6″ which facilitated a clear picture of the kicks. The GoPro-11 Camera has the following features: 27 Megapixel, 5.3K60/2.7K240 Video, 27 Megapixel Photos, Hyper-Smooth 5.0 Image Stabilization, Front & Rear LCD Screens, Wi-Fi & Bluetooth Connectivity, 33' Waterproof without Housing, 8x Slow-Motion Video, 1720mAh Capacity Rechargeable Battery. Following the camera setup, all the penalty kicks were recorded and transferred to a computer installed with the 2D motion analysis software Kinovia 0.8.15 (France).
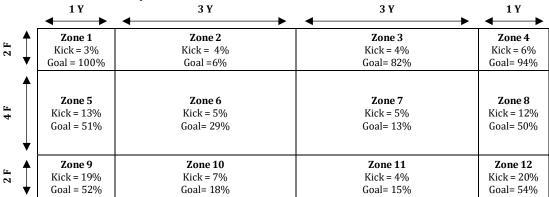
Data collection and extraction

The Penalty kick's target Zone was identified by visual observation and video footage recordings. Recorded videos analyzed with the help of motion analysis software called KINOVEA. To eliminate any doubt about the ball approaching the zone, researchers conducted a double-check. When the ball is saved by the goalkeeper, the zone is determined according to the direction the ball is approaching towards the goal.

Statistical analysis

In Descriptive Statistics, the percentage was employed, and in Inferential Statistics, a Chi-square test was conducted to reveal association, as these data were categorical.

Results

Figure 2. Distribution of Kicks and Goals by Zones

N.B.: F = Feet, Y = Yard
Source: Chanda et al. (2025).

Table 1. Sequence of vulnerable zones at goal and zone-specific goal-scoring percentages

Vulnerable zone	1	4	3	2	12	9	5	8	6	10	11	7
Goal %	100	94	82	64	54	52	51	50	29	18	15	13

Note: Chanda et al. (2025).

The order of vulnerable zones at the goal and their goal-scoring percentages unveil a distinct pattern in scoring efficiency among different zones. The result shows the sequence of highest goal-scoring percentages are observed in zone 1 (100%), zone 4 (94%), zone 3 (82%), zone 2 (64%), zone 12 (54%), zone 9 (52%), zone 5 (51%), zone 8 (50%), zone 6 (29%), zone 10 (18%), zone 11 (15%), and zone 7 (13%). [Table 1]

Table 2. The sequence of attack zones in ascending order and penalty kick % at goal in football

Zone	12	9	5	8	10	4	6	7	3	2	11	1
Kick %	20	19	13	12	7	6	5	5	4	4	4	3

Note: Chanda et al. (2025).

The sequence of attack zones and their respective kicking percentages highlight a unique trend in the distribution of penalty kicks targeting different zones of the goal. The findings indicate that the kick percentages are ordered from highest to lowest as follows in zone 12 (20%), zone 9 (19%), zone 5 (13%), zone 8 (12%), zone 10 (12%), zone 4 (6%), zone 6 (5%), zone 7 (5%), zone 3 (4%), zone 2 (4%), zone 11 (4%), and zone 1 (3%). [Table 2]

Table 3. Count and expected count table of zones in goal * goal scoring

			Goal		Total
			Save	Goal	
Zones in goal	Zone 1	Count	0	10	10
		Expected count	4.9	5.1	10.0
	Zone 2	Count	2	9	11
		Expected count	5.4	5.6	11.0
	Zone 3	Count	2	9	11
		Expected count	5.4	5.6	11.0
	Zone 4	Count	1	17	18
		Expected count	8.8	9.2	18.0
	Zone 5	Count	19	20	39
		Expected count	19.0	20.0	39.0
	Zone 6	Count	10	4	14
		Expected count	6.8	7.2	14.0
	Zone 7	Count	13	2	15
		Expected count	7.3	7.7	15.0
	zone 8	Count	18	18	36
		Expected count	17.5	18.5	36.0
	zone 9	Count	28	30	58
		Expected count	28.3	29.7	58.0
	Zone 10	Count	18	4	22
		Expected count	10.7	11.3	22.0
	Zone 11	Count	11	2	13
		Expected count	6.3	6.7	13.0
	Zone 12	Count	29	34	63
		Expected count	30.7	32.3	63.0
Total		Count	151	159	310
		Expected count	151.0	159.0	310.0

Note: Chanda et al. (2025).

Table 4. Chi-square test among 12 zones of goal

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	59.234	11	.000
N of valid cases	310		

Cells (4.2%) have an expected count less than 5. The minimum expected count is 4.87.
Note: Chanda et al. (2025).

Table 5. Measure of Association between zones in goal and outcomes (Goal or Save)

Symmetric Measures		Value	Approximate Significance
Nominal by Nominal	Phi	.437	.000
	Cramer's V	.437	.000
N of Valid Cases		310	

Note: Chanda et al. (2025).

It is observed from Tables 3, 4, and 5 that Pearson's Chi-square test value is 59.234, df is 11, and p= .000, suggesting a statistically significant association between the zones in the goal and the outcomes (goal or save). Further, it confirms the validity of the results, as only 4.2% of cells have an expected count of less than 5 and the minimum expected count is 4.87. In the symmetric measures, for both Phi and Cramer's V test value is .437 with p = .000, which further confirms the statistical significant of the tests and indicates a relatively strong relationship between zones and outcomes. The result shows that the distribution of goals and saves is not uniform across the zones and some zones may be more vulnerable to goals. The study reveals a statistically significant association between goal zones and outcomes, demonstrating that goal distribution varies across zones, with some being more susceptible to goals.

Discussion

The study looks at the sequence of critical areas within the goal during penalty kicks, underscoring the dual benefits for goalkeepers and kickers through targeted, zone-specific training to improve their respective performance. It was hypothesized that "There is no statistically significant difference in vulnerability across various zones in soccer goal in terms of frequency of penalty kicks and rate of goal scoring" has been rejected as there are differences in frequency and scoring across the zones.

Zones located further from the middle of the goal line exhibited a corresponding rise in vulnerability. The most vulnerable zones of the goal are Zone 1 (left top corner) and Zone 4 (right top corner) where the goal-scoring chance is nearly a hundred percent. Following these, zones 3 and 2 situated in the middle-top positions also show notable vulnerability. Specifically, zones 5, 8, 9, and 12 - situated in the farthest bottom and middle-right and left locations are the next most vulnerable with roughly fifty percent scoring chances. The bottom and middle right and left zones, including zones 6, 10, 11, and 7 are less vulnerable, while zone 7 is the least vulnerable among them. The success rates of penalty kicks in different zones of the goal are different in football (Dohmen, 2008). Due to the gravity of the earth, it is always difficult for goalkeepers to jump high and far. For higher and farther jumps athletes need to manage the center of gravity (CG) of the body, body posture, and muscle force as the gravity of the earth makes it challenging (Qiao & Dong, 2022). It is evidenced that a good jump by the goalkeeper is highly correlated with his lower limbs means leg dimensions (Flores-Moreno et al., 2023). The condition necessitates that the goalkeeper exhibit robust leg strength, quick reaction time, adequate body height, and a sharp sense of the ball's trajectory and spin. Leg strength and quick reaction time have potential benefits for football goalkeepers (Slimani et al., 2018). Regarding height, goalkeepers are generally the tallest player on the field compared to those players who play in other positions (Joksimović et al., 2019). From the Biomechanical perspective of the goalkeepers' dive where they lean forward, bend their knees, rotate their hips outward, and keep their feet 70-75% of their leg length apart to react fast and adjust movements for better shot-stopping to save their goal (Jin, 2024). Further, it indicates that goalkeepers are weaker on their left-hand side. Left-hand reaction time is slower than that of the right hand (Bestelmeyer & Carey, 2004) as most peoples' preferred hand is the right hand (Cochet & Vauclair, 2012). Besides, goalkeepers likely find it easier to reach the farthest zones near the ground compared to the higher zones as their vulnerability in these higher zones suggests. The Goalkeeper's body center of gravity (CG) point usually remains within the middle zones of the goal. Moving the center of gravity downward is easier than moving upward (Claassen et al., 2016). In general, the results of the study delineate that the goalkeepers are most vulnerable in the farthest zones from the middle of the goal, mainly in zones 1 (left bottom corner) and 4 (right bottom corner), where increasing vulnerability is observed in higher and farther zones.

Penalty kickers predominantly aim toward the sides near the barposts that are close to the ground, which is approximately twenty percent targeting each of zones 12 and 9. Kicking a ball along the ground is more accurate than aerial kicks (Pepping et al., 2011). It is noticed that field players attempted penalty kicks four times more in the lower zones compared to the upper zones (Navia et al., 2019). The following highest percentage of attacks occurs in the two middle-ends zones 5 and 8 with just over one-tenth of the kicks on each targeting these areas. In the lower two middle zones 10 and 11 attacked seven percent and four percent of the kicks respectively. At the top two corners of the goal zone, zones 4 and 1 received six percent and three percent of the kickers respectively. Next, zones 6 and 7 in the middle each received five percent of the kicks, while zones 2 and 3 each targeted four percent of the penalty kicks. The lowest percentage of the kicks were directed at zone 1, while the highest percentage of kicks targeted zone 12. This information is extracted from the Table 2. The literature suggests that if the penalty kick is taken at the difficult areas of the goal to reach by the goalkeepers with higher velocity increases the probability of goal scoring in association football (Leela & Comissiong, 2009). Top-notch football players prefer near-to-ground shots on the goal (Pertsukhov et al., 2020). Further, training designed for the kicks by geometric simplification means dividing goal into different segments increases the chance of scoring in football (Morales, 2018).

Pearson's chi-square value is 59.234 with df = 11 and p = .000 suggesting a statistically significant association between the goal zones and the outcomes (goal or save). Since only 4.2% of cells have an expected count of less than 5 and the minimum expected cunt is 4.87, this confirms the validity of the

results. It is widely practiced in the field of statistics that if fewer than 20% of the cells have expected counts, the chi-square test is usually still considered valid (Campbell, 2007). Phi and Cramer's *V* value of .437 and *p* = .000 in the symmetric measures, the tests further confirm their statistical significant and suggest a relatively strong relationship between zones and outcomes as 0: no relationship, V<0.10: negligible relationship, 0.10<V<0.20: weak relationship, 0.20<V.40: moderate relationship, 0.40<V<0.60: relatively strong relationship (Gruss et al., 2015). The analysis confirms a statistically significant and relatively strong association between goal zones and outcomes such as goal or save, with chi-square test results further validating and indicating that goal scoring varies by zone. It is reported that goalkeepers faced varying levels of difficulty across various zones of the goalpost during penalty kicks when analyzed by dividing the goal into different zones (Bar-Eli & Azar, 2009). In addition, some studies disclose that for defending against penalty kicks goalkeepers encounter varying levels of difficulty across different zones of the goalpost containing both weak and strong zones (Barbero et al., 2023; Noël et al., 2015). Therefore, previous studies cited in the paragraph show consistency with the present findings which in the same way identifies goal scoring and save are not equal across the zones of the goal in penalty shootouts.

Soccer coaches can take dwell benefit by applying these study findings in their coaching to design zone-specific training plans for penalty kickers and goalkeepers. The study results open up the prospect for future research that could explore how targeted training for penalty kickers and goalkeepers can improve performance by addressing the differences in vulnerability throughout goal zones, with an emphasis on increasing leg strength, reaction time, body mechanics, different age groups and genders, as well as investigative the psychological aspects contributing to the decision-making process in penalty kicks.

Conclusions

In conclusion, the paper elucidated the vulnerable zones of the goal during penalty shootouts and offered important insights into the strategic areas where goalkeepers and kickers are most and least effective. Most kicks are predominantly targeted at the lower sides of the goalposts, with a decreasing number of kicks towards higher and farther areas, and the least number of kicks reach the top corners. The likelihood of scoring increases during penalty kicks in football as the ball is kicked farther from the midpoint of the goal line, with the scoring chance further improving when kicked higher and further away. Goal and save distribution varies by zone and some zones are more vulnerable to goals. The findings of the study suggest that football coaches should train goalkeepers to defend better in the lower and far edges of the goal because penalty kicks are most often targeted at these areas, while penalty kickers should train to take kicks for the top corners of the goal where the likelihood of scoring is much higher despite being more challenging for the goalkeepers to reach.

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