

Analysis of soccer goalkeeper performance and shot scenarios in the 2022 World Cup

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Abstract

Problem Statement: In soccer, teams seldom achieve victory by scoring multiple goals, therefore, preventing goals is crucial for winning matches. The goalkeeper plays a pivotal role in this aspect by blocking shots from opposing players considerably impacting the game's outcome. However, the connection between the characteristics of shot situations and the movements of goalkeepers is not well understood. **Purpose:** This study aimed to enhance goalkeeper training strategies by analyzing the relationship between shot situations and goalkeeper movements during the 2022 FIFA World Cup in Qatar. **Approach:** The research categorized 432 on-target shots from all 64 matches based on factors such as location, outcome, body part used, and the events leading up to each shot. Goalkeeper actions were classified into diving after preparatory motion, stepping and diving after preparatory motion, and blocking. **Results:** Areas near the center of the goal are dangerous for goalkeepers, with a higher frequency of goals than expected. This study found that goalkeepers commonly used diving after preparatory motion, highlighting its importance across all areas. However, blocking occurred more frequently in high-pressure areas where time and spatial constraints are more significant, suggesting the need to prioritize this technique to reduce shooting angles and increase shot-stopping success. In contrast, a higher incidence of catching, stepping, and diving after preparatory motion was observed in areas farther from the goal where goalkeepers had more time to react. These areas also had more controlled shots, often involving two or more touches. **Conclusions:** This study suggests that goalkeeper training should be tailored to different shot locations, focusing on quick, reactive movements, such as blocking dangerous areas and positioning, and controlled dives in less pressurized areas. This study provides a framework for designing goalkeeper training sessions that reflect actual match conditions, emphasizing the need for scenario-based practices. Future research could refine these strategies by considering additional factors, such as the specific foot used for shooting and the exact placement of the shot on the goal.

Key Words: 2022 FIFA World Cup, goalkeeper movements, scenario-based practice, soccer

Introduction

In soccer matches, victory is rarely achieved by scoring many goals. Therefore, goal prevention is crucial for winning matches. The performance of the goalkeeper (GK), who defends the goal against shots from the opposing players (hereafter referred to as “shot-stopping”), considerably impacts the outcome of the game. Consequently, studies analyzing soccer matches have measured various performance metrics for field players and GKs.

Di Salvo et al. (2008) analyzed the distance and speed of GK movements in 109 matches in the English Premier League. The average distance covered by GKs per match was $5,611 \pm 613$ m, with no significant difference between the first and second halves of the matches. Furthermore, high-intensity movements (at speeds of 19.9 km/h or more) accounted for only 2% of the total distance covered; however, these high-intensity movements were closely related to the outcomes of the matches. Furthermore, GKs performed the most actions in the following order during the 2002 World Cup: diving after preparing for shot-stopping, ball control—such as passing—and clearing through punching or kicking (Sainz De Baranda et al., 2008). In the 2008 European Championship, offensive actions occurred more frequently than defensive actions, with most involving ball control, including passing (Szwarc et al., 2010). However, because the primary role of a GK during a game is shot-stopping, measuring the metrics related to shots and shot-stopping is essential to accurately evaluate GK performance.

Studies that have measured metrics related to shots have examined the patterns of scoring in the tournament and their relationship to final standing, focusing on factors such as the timing of goals, the plays immediately preceding the goals, and the locations of shots. A substantially higher number of shots are taken from inside the penalty area than from outside (Yiannakos & Armatas, 2006; Armatas et al., 2009; Michailidis et al., 2013; Charalampous et al., 2013; Çobanoglu, 2019), and teams with more shots perform better in league

standings than those with fewer shots (Evangelos et al., 2013; Numazu et al., 2024). Such analyses of scoring trends are equivalent to analyzing trends in conceding goals to GKs. Therefore, analyzing shot situations from recent tournament settings will provide valuable insights for GKs.

Studies examining the relationship between GK movements and shots during matches have focused on measuring the actions of GKs in relation to shot-stopping. Numazu et al. (2017) analyzed university soccer league matches in Japan by measuring the locations and heights of shots, preparatory motions, and diving after preparatory motion, similar to the tennis split-step performed by GKs during shot-stopping. The GKs often performed preparatory motions regardless of whether they successfully stopped the shot or not. However, GKs often do not perform preparatory motions when they fail to stop the shot. The most frequently observed action was a continuous sequence of steps and dives after preparatory motions.

Matsukura and Hirashima (2020) investigated the relationship between the preparatory motions of GKs and the conditions under which shots were taken during the 2018 FIFA World Cup in Russia. GKs commonly performed preparatory motions involving jumps while widening their stance. Additionally, shots taken closer to the goal and more central areas (hereafter referred to as “danger areas”) resulted in more frequent goals than expected. They also provided insights into training planning based on the relationship between danger areas, the number of touches leading to the shot, and the actions of the GKs. They suggested that GKs must plan training sessions that reflect the analysis of the play during actual match scenarios to master their movements efficiently.

Matsukura et al. (2024) examined the relationship between diving after preparatory motion and the shot conditions during Russia's 2018 FIFA World Cup. GKs chose and executed optimal actions under the temporal and spatial constraints of incoming shots to reach the ball effectively. Isolating and practicing the movement itself and recreating shot situations in which these movements are most likely to occur is essential when planning to dive after preparatory motion. Thus, when evaluating goalkeeper performance in shot situations, it is essential to consider the number of touches leading to the shot (Matsukura et al., 2024), as well as the relationship between movements of the GK and preceding plays, such as crosses, passes, or dribbles. However, the relationship between the plays leading to the shot and GK actions has not been investigated in detail (Hirashima et al., 2014; Hirashima et al., 2018; Numazu et al., 2017; Matsukura & Hirashima, 2020; Matsukura et al., 2024). Official records published on the FIFA Training Center website

(<https://www.fifatrainingcentre.com/en/fwc2022/post-match-summaries/post-match-summary-reports.php#>) provide comprehensive information on all shot situations from every match in the 2022 FIFA World Cup in Qatar. The relationship between the plays leading to the shots and the actions of GKs can be investigated by combining the measurement of GK movements from match footage (Numazu et al., 2017; Hirashima et al., 2018; Matsukura & Hirashima, 2020; Matsukura et al., 2024) with official records detailing the shot conditions and body parts used to take the shots. This approach offers specific insights into planning GK training sessions.

This study aimed to clarify the relationship between the characteristics of shot situations and GK movements during the 2022 FIFA World Cup in Qatar to provide specific insights for planning training sessions. The following hypotheses were formulated for this study based on previous research (Hirashima et al., 2014; Hirashima et al., 2018; Matsukura & Hirashima, 2020; Matsukura et al., 2024):

1. The number of touches that lead to a shot varies depending on the location from which the shot is taken (Matsukura et al., 2024). Therefore, the location of the shot could influence the frequency of the plays leading to the shot and the body parts used to execute the shot.

2. GKs choose optimal actions in response to the situation and adapt to the shot accordingly (Matsukura et al., 2024). Furthermore, GKs frequently use continuous movements, transitioning from steps and diving after preparatory motion to respond to shots (Numazu et al., 2017). Consequently, GKs will use this continuous movement pattern more frequently in areas with a high volume of shots, such as the danger areas, than outside these areas (Matsukura & Hirashima, 2020).

Material & methods

Definition of terms

Preparatory motion is defined as “a small jump or step motion initiated as a cue to start moving when a shot is taken” (Numazu et al., 2017; Matsukura & Hirashima, 2020).

A diving motion is defined as an action in which the GK jumps to the side and stops the shot using their hands or arms. Stepping is defined as “the clear lateral movement of the GK, such as a side or cross-stepping, before performing a diving motion.” Catching refers to the action in which the GK catches the ball with their hands without performing a diving motion. Watching is defined as the action of the GK when they are unable to respond to a shot, resulting in a goal (Numazu et al., 2017).

Matches

This study focused on all 64 matches in the 2022 FIFA World Cup in Qatar tournament. The actions of the GKs were measured using match footage available on Abema TV, a Japanese Internet broadcasting service, until March 31, 2023. Analyzing world-class matches often relies on broadcast footage (Matsukura & Hirashima, 2020). However, broadcasted footage typically focuses on the player taking the shot, sometimes resulting in an inability to observe the actions of the GK. Therefore, this study analyzed 432 scenes out of the 517 shots labeled “on target” in the official records after excluding shots taken from penalty kicks, direct free kicks, and shots

directed toward the goal from corner kicks as previously described (Numazu et al., 2017; Matsukura & Hirashima, 2020). These exclusions were made to ensure that the focus was on in-game shot-stopping situations. Of the 432 scenes analyzed, 144 resulted in goals. The analyzed plays were assumed to be independent for statistical analysis.

Measurement items

Classification of shot scenes and shot outcome

Each shot was classified and measured based on five items: shot outcome, shot area, body part used for the shot, situation immediately before the shot, and frequency of ball touches by the shooter before taking the shot (hereafter referred to as “frequency of the ball touches”).

The official records where goals were labeled “goal” and shots on target that did not result in a goal were labeled “on target” were used to distinguish the success or failure of shot-stopping.

Shot locations

Shot locations were classified into six types based on the combination of distance to the goal (two categories) and angle to the goal (three categories; Figure 1) (Matsukura & Hirashima, 2020; Matsukura et al., 2024). A semicircle with a radius of 16.5 m—which is the length of the penalty area—was drawn from the center of the goal to determine the distance to the goal. The area inside the semicircle was classified as “near” and outside as “far.” Two lines were used for the angle to the goal: one passing through the intersection of the penalty arc and the line marking the edge of the penalty area (parallel to the goal line), and another passing through the corners of the penalty area from the goalpost as the origin. The three areas created by these lines were classified as A, B, and C. To facilitate measurement, the shot location images from the official records were imported into Microsoft PowerPoint (Microsoft, Redmond, WA, USA), where the semicircles and lines were drawn on the images for measurement. The near and far are denoted as AN, BN, and CN for near and AF, BF, and CF for far.

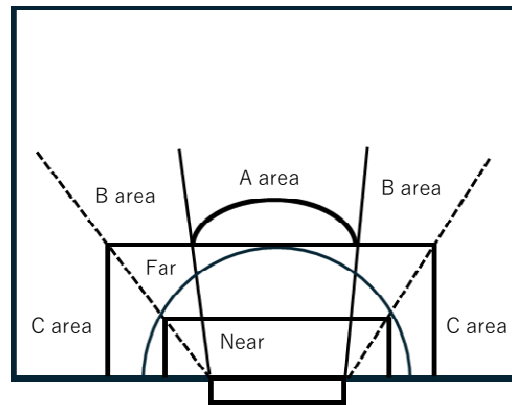


Figure 1. categorization of shot locations.

Body part used for the shot and situation immediately before the shot

Based on the official record's “body part” category, shots taken with the legs (right and left foot) were combined into a single category, namely, “leg,” resulting in three categories: head, body, and leg.

The situation immediately before the shot was classified into seven categories using the official record's “delivery type” category: pass, cross, ball progression (meaning a play that carries the ball toward the opponent's goal), loose ball, intercept, tackle, and other (for plays not included in the six categories). Upon reviewing the video footage during the measurement, it was noted that balls delivered into the penalty area targeting the space behind the defensive line were recorded as passes in the official records.

Frequency of ball touches

The frequency of ball touches was classified based on whether the shooter controlled the ball with any body part before shooting, after receiving a pass, or after crossing from a teammate. If the shooter took the shot without controlling the ball, it was classified as “one touch.” If the shooter controlled the ball (including dribbling) before the shot, it was classified as “two touches or more.” The frequency of ball touches was measured by visually observing the match footage.

Classification of GK movements

The GK shot-stopping actions were measured for each shot scene. Shot-stopping actions consist of two phases: preparatory and diving motions (Matsukura & Hirashima, 2020). The shot-stopping actions were classified as follows: Measurements were conducted by repeatedly playing and pausing satellite-broadcasted matches, similar to the methods used by Numazu et al. (2017) and Matsukura and Hirashima (2020). A detailed analysis was not performed because the effectiveness and actual usage frequency of preparatory motion have already been reported (Uzu et al., 2009; Numazu et al., 2017; Matsukura & Hirashima, 2020). Diving motions were classified into nine categories as previously described (Numazu et al., 2017): 1. Diving after preparatory

motion: The GK performed preparatory and diving motions. 2. Stepping and diving after preparatory motion: The GK stepped immediately after the preparatory motion, followed by diving. 3. Stepping and diving without preparatory motion: The GK performed the diving motion directly after a lateral movement without any preparatory motion. 4. Diving only: The GK performed the diving motion without any preparatory or lateral movements. 5. Parrying: The GK deflected the ball near their head with their hands or body without an apparent diving motion. 6. Catching: This category was recorded only when the GK successfully stopped the shot by catching it. 7. Blocking: The GK approached the shooter and used their body to block them. 8. Responding to a second attack: The GK had already responded to a previous play (such as diving or blocking) and was unable to respond to the shot. 9. Watching: This category was recorded only when the GK failed to stop the shot.

Statistical analysis

Objectivity

The objectivity of the measured data must be assessed when using the data obtained from observers watching match footage (Suzuki & Nishijima, 2002; Hirashima et al., 2018; Numazu et al., 2017; Matsukura & Hirashima, 2022; Matsukura et al., 2024). Therefore, the objectivity was verified by calculating the kappa (κ) coefficients for four measurement items: shot area, frequency of ball touches, preparatory motion, and diving motion, based on the data obtained by the two observers. The κ coefficients were calculated using 131 shot scenes from the 2022 FIFA World Cup in Qatar tournament, the same as the study sample. The observers were two individuals engaged in soccer science research, both holding coaching licenses from the Japan Football Association and with experience playing and coaching GKs. Because the measurement involved repeated pausing and playing footage, each observer conducted the measurements independently.

Comparing measurement items

Different statistical tests were used to compare the measurement items. A significance level of 5% was set for statistical processing, and the chi-square test for independence was conducted using IBM SPSS Statistics v. 29 for all data processing. Adjusted residuals were calculated to extract the items with significant differences when significant differences were observed. The effect size in the chi-square test was determined by calculating Cramer's V, with values < 0.1 considered no effect, 0.1 to < 0.3 as small, 0.3 to < 0.5 as medium, and ≥ 0.5 as significant (Cohen, 1988).

Results

Objectivity of observed data

Table 1 shows the κ coefficients for the shot area, frequency of ball touching, and diving motion. The κ coefficients indicated almost perfect agreement for shot-related items and substantial agreement for GK movements.

Table 1. κ coefficients for the shot area, frequency of ball touching, and diving motion.

Measurement item	Kappa coefficient	Strength of agreement
Shot area	0.97	Almost perfect
Frequency of the ball touching before shot	0.89	Almost perfect
Preparatory motion	0.56	Moderate
Diving motion	0.71	Substantial

Measurement item	Kappa coefficient	Strength of agreement
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Match characteristics

Shot characteristics

Table 2 presents the 432 on-target shots in which the GK actions were measurable and categorized by shot outcome, area, and situation. Unless otherwise noted, the numbers in parentheses indicate the expected values of each item. The relationship between shot outcome and area shows that goals were significantly more frequent than expected in areas AN and BN, whereas saves were significantly more frequent than expected in areas AF, BF, and CF (Table 2a; $\chi^2 = 76.30$, $p < 0.01$, Cramer's V = 0.420). The relationship between shot outcome and situation indicates that shots from crosses resulted in significantly more goals than expected, whereas shots from passes and ball progression resulted in significantly more saves than expected (Table 2b; $\chi^2 = 25.56$, $p < 0.001$, Cramer's V = 0.243).

Table 2. On-target shots in which GK actions are categorized by shot outcome, area, and situation.

(a) Shot area	AN	BN	CN	AF	BF	CF
Save						
Observed value (expected value)	68 (99.3)	47 (56.7)	21 (19.3)	60 (44.7)	70 (51.3)	22 (16.7)
Adjusted residual error	-6.7	-2.5	0.7	4.3*	5.0*	2.3*
Goal						
Observed value (expected value)	81 (49.7)	38 (28.3)	8 (9.7)	7 (22.3)	7 (25.7)	3 (8.3)
Adjusted residual error	6.7*	2.5*	-0.7	-4.3	-5.0	-2.3
Statistical result	$\chi^2 = 76.30$ df = 5 p < 0.01 Cramer's V = 0.420					

AN: A Near, BN: B Near, CN: C Near, AF: A Far, BF: B Far, CF: C Far

(b) Shot situation	B	C	I	L	P	T	O
Save							
Observed value (expected value)	22 (16.7)	37 (54.0)	1 (0.7)	32 (34.7)	166 (154.7)	3 (2.7)	27 (24.7)
Adjusted residual error	2.3*	-4.4	0.7	-0.8	2.3*	0.4	0.9
Goal							
Observed value (expected value)	3 (8.3)	44 (27.0)	0 (0.3)	20 (17.3)	66 (77.3)	1 (1.3)	10 (12.3)
Adjusted residual error	-2.3	4.4*	-0.7	0.8	-2.3	-0.4	-0.9
Statistical result	$\chi^2 = 25.56$ df = 6 p < 0.001 Cramer's V = 0.243						

B: Ball progression, C: Cross, I: Intercept, L: Loose ball, P: Pass, T: Tackle, O: Other

Table 3 lists the 432 on-target shots categorized by shot area and the situation immediately before the shot. In area AN, the number of shots from crosses was significantly higher than expected, whereas the number of shots from passes and ball progressions was significantly lower than expected. In area CN, the number of shots from the ball progression was significantly higher than expected. In areas AF, BF, and CF, the number of shots from passes was significantly higher than expected, whereas the number of shots from crosses was significantly lower. Additionally, in area CF, the number of shots from ball progression was significantly higher than expected ($\chi^2 = 115.23$, $p < 0.001$, Cramer's V = 0.231).

Table 3. On-target shots categorized by shot area and the situation immediately before the shot.

	B	C	I	L	P	T	O
AN	1 (8.6)	56 (27.9)	0 (0.3)	20 (17.9)	57 (80.0)	0 (1.4)	15 (12.8)
Adjusted residual	-3.3*	7.3*	-0.7	0.6	-4.7*	-1.5	0.8
BN	4 (4.9)	21 (15.9)	0 (0.2)	6 (10.2)	48 (45.6)	2 (0.8)	4 (7.3)
Adjusted residual	-0.5	1.6	-0.5	-1.6	0.6	1.5	-1.4
CN	5 (1.7)	3 (5.4)	0 (0.1)	6 (3.5)	12 (15.6)	0 (0.3)	3 (2.5)
Adjusted residual	2.7*	-1.2	-0.3	1.5	-1.4	-0.5	0.4
AF	4 (3.9)	0 (12.6)	1 (0.2)	11 (8.1)	44 (36.0)	1 (0.6)	6 (5.7)
Adjusted residual	0.1	-4.3*	2.3*	1.2	2.1*	0.5	0.1
BF	7 (4.5)	1 (14.4)	0 (0.2)	9 (9.3)	51 (41.4)	1 (0.7)	8 (6.6)
Adjusted residual	1.4	-4.3*	-0.5	-0.1	2.4*	0.4	0.6
CF	4 (1.4)	0 (4.7)	0 (0.1)	0 (3.0)	20 (13.4)	0 (0.2)	1 (2.1)
Adjusted residual	2.3*	-2.5*	-0.2	-1.9	2.7*	-0.5	-0.8
Statistical result	$\chi^2 = 115.23$ df = 30 p < 0.001 Cramer's V = 0.231						

AN: A Near, BN: B Near, CN: C Near, AF: A Far, BF: B Far, CF: C Far

B: Ball progression, C: Cross, I: Intercept, L: Loose ball, P: Pass, T: Tackle, O: Other

Table 4 presents the 432 on-target shots categorized by the frequency of ball touches, shot area, and the situation immediately before the shot. The relationship between the frequency of ball touches and shot area shows that in area AN, the number of one-touch shots was significantly higher than expected (Table 4a). In areas AF, BF, and CF, the number of shots with two or more touches was significantly higher than expected ($\chi^2 = 100.13$, $p < 0.001$, Cramer's $V = 0.481$). The relationship between the frequency of ball touches and the shot situation shows that the number of one-touch shots was significantly higher than expected for shots from crosses (Table 4b). For shots from ball progression, passes, and tackles, the number of shots with two or more touches was significantly higher than predicted ($\chi^2 = 102.96$, $p < 0.001$, Cramer's $V = 0.452$).

Table 4. On-target shots categorized by the frequency of ball touches, shot area, and the situation immediately before the shot.

(a)	AN	BN	CN	AF	BF	CF
1 touch	123 (82.8)	52 (47.2)	18 (16.1)	22 (37.1)	17 (42.8)	8 (13.9)
Adjusted residual	8.2*	1.2	0.7	-4.1	-6.5	-2.4
2 touches more	26 (66.2)	33 (37.8)	11 (12.9)	45 (29.8)	60 (34.2)	17 (11.1)
Adjusted residual	-8.2	-1.2	-0.7	4.1*	6.5*	2.4*
statistical result	$\chi^2 = 100.13$	df = 5	p < 0.001	Cramer's V = 0.481		
AN: A Near, BN: B Near, CN: C Near, AF: A Far, BF: B Far, CF: C Far						

(b)	B	C	I	L	P	T	O
1 touch	2 (13.9)	75 (45.0)	0 (0.6)	32 (28.9)	105 (128.9)	0 (2.2)	26 (20.6)
Adjusted residual	-4.9	7.4*	-1.1	0.9	-4.6	-2.2	1.9
2 touches more	23 (11.1)	6 (36.0)	1 (0.4)	20 (23.1)	127 (103.1)	4 (1.8)	11 (16.4)
Adjusted residual	4.9*	-7.4	1.1	-0.9	4.6*	2.2*	-1.9
statistical result	$\chi^2 = 102.96$	df = 5	p < 0.001	Cramer's V = 0.452			
B: Ball progression, C: Cross, I: Intercept, L: Loose ball, P: Pass, T: Tackle, O: Other							

Table 5 shows the 432 on-target shots categorized according to the body parts used for the shot, the shot area, and the situation immediately before the shot. The relationship between the body part used and shot area shows that in area AN, the number of shots with the head and body was significantly higher than expected, whereas the number of shots with the leg was significantly lower than expected (Table 5a). In areas AF, BF, and CF, the number of shots using the leg was significantly higher than expected, whereas the number of shots with the head and body was significantly lower than expected ($\chi^2 = 69.64$, $p < 0.001$, Cramer's $V = 0.284$). The relationship between the body part and the shot situation shows that for shots from ball progression and passes, the number of shots using the leg was significantly higher than expected, whereas the number of shots with the head was significantly lower than expected (Table 5b). For shots from crosses, the number of shots with the head and body was significantly higher than expected, whereas the number of shots with the leg was significantly lower than expected ($\chi^2 = 89.98$, $p < 0.001$, Cramer's $V = 0.323$).

Table 5. On-target shots categorized according to the body parts used for the shot, the shot area, and the situation immediately before the shot.

(a)	AN	BN	CN	AF	BF	CF
Leg	100 (126.2)	71 (72.0)	27 (24.6)	66 (56.8)	77 (65.2)	25 (21.2)
Adjusted residual	-7.4*	-0.3	1.3	3.4*	4.1*	2.2*
Head	41 (19.7)	14 (11.2)	1 (3.8)	1 (8.8)	0 (10.2)	0 (3.3)
Adjusted residual	6.4*	1.0	-1.6	-3.1*	-3.8*	-2.0*
Body	8 (3.1)	0 (1.8)	1 (0.6)	0 (1.4)	0 (1.6)	0 (0.5)
Adjusted residual	3.5*	-1.5	0.5	-1.3	-1.4	-0.8
Statistical result	$\chi^2 = 69.64$	df = 10	p < 0.001	Cramer's V = 0.284		
AN: A Near, BN: B Near, CN: C Near, AF: A Far, BF: B Far, CF: C Far						

(b)	B	C	I	L	P	T	O
Leg	25 (21.2)	42 (68.6)	1 (0.8)	45 (44.1)	218 (196.9)	4 (3.4)	31 (31.3)
Adjusted residual	2.2*	-9.1*	0.4	0.4	5.8*	0.9	-0.1
Head	0 (3.3)	34 (10.7)	0 (0.1)	5 (6.9)	13 (30.6)	0 (0.5)	5 (5.0)
Adjusted residual	-2.0*	8.5*	-0.4	-0.8	-5.0*	-0.8	0.0
Body	0 (0.5)	5 (1.7)	0 (0.0)	2 (1.1)	1 (4.8)	0 (0.1)	1 (0.8)
Adjusted residual	-0.8	2.9*	-0.1	0.9	-2.6*	-0.3	0.3
Statistical result	$\chi^2 = 89.98$	df = 12	p < 0.001	Cramer's V = 0.323			

B: Ball progression, C: Cross, I: Intercept, L: Loose ball, P: Pass, T: Tackle, O: Other

Relationship between shots and diving motions

Table 6 shows the 432 on-target shots categorized by the GK actions and shot areas. The most frequently observed action was diving after preparatory motion. However, no significant results indicated that this action was used often in specific shot areas. Stepping and diving after preparatory motion were significantly more frequent than expected in area BF. Stepping and diving without preparatory motion were significantly more frequent than expected in area AN. Catching was significantly more frequent than expected in areas AF and BF but significantly less frequent in areas AN, BN, and CN. Parrying was significantly more frequent than expected in the CF area. Blocking was significantly more frequent than expected in areas AN and CN but significantly less frequent in areas AF and BF. Responding to a second attack was significantly more frequent than expected for AN. Watching was significantly more frequent than expected in area BN but significantly less frequent in areas AF and BF ($\chi^2 = 139.28$, $p < 0.001$, Cramer's V = 0.432).

Table 6. On-target shots categorized by the GK actions and shot areas.

GK's motion × Shot area	AN	BN	CN	AF	BF	CF
1. Diving after preparatory motion	46 (54.8)	35 (31.3)	9 (10.7)	27 (24.7)	34 (28.3)	8 (9.2)
Adjusted residual	-1.9	0.9	-0.7	0.6	1.5	-0.5
2. Stepping and diving after preparatory motion	1 (3.4)	0 (2.0)	1 (0.7)	3 (1.6)	5 (1.8)	0 (0.6)
Adjusted residual	-1.6	-1.6	0.4	1.3	2.7*	-0.8
3. Stepping and diving without preparatory motion	5 (1.7)	0 (1.0)	0 (0.3)	0 (0.8)	0 (0.9)	0 (0.3)
Adjusted residual	3.1*	-1.1	-0.6	-1	-1	-0.6
4. Diving only	5 (2.8)	2 (1.6)	1 (0.5)	0 (1.2)	0 (1.4)	0 (0.5)
Adjusted residual	1.7	0.4	0.7	-1.2	-1.3	-0.7
5. Catching	26 (35.9)	10 (20.5)	1 (7.0)	32 (16.1)	27 (18.5)	8 (6.0)
Adjusted residual	-2.3*	-3.0*	-2.7*	4.9*	2.5*	1
6. Parrying	8 (12.1)	8 (6.9)	3 (2.3)	3 (5.4)	7 (6.2)	6 (2.0)
Adjusted residual	-1.5	0.5	0.5	-1.2	0.4	3.0*
7. Blocking	30 (21.7)	17 (12.4)	11 (4.2)	1 (9.8)	3 (11.2)	1 (3.6)
Adjusted residual	2.4*	1.6	3.7*	-3.3*	-2.9*	-1.5
8. Responding to a second attack	11 (4.1)	0 (2.4)	1 (0.8)	0 (1.9)	0 (2.1)	0 (0.7)
Adjusted residual	4.2*	-1.7	0.2	-1.5	-1.6	-0.9
9. Watching	17 (12.4)	13 (7.1)	2 (2.4)	1 (5.6)	1 (6.4)	2 (2.1)
Adjusted residual	1.7	2.6*	-0.3	-2.2*	-2.5*	-0.1
statistical result	$\chi^2 = 139.28$	df = 40	p < 0.001	Cramer's V = 0.432		

AN: A Near, BN: B Near, CN: C Near, AF: A Far, BF: B Far, CF: C Far

Table 7 presents the 432 on-target shots categorized by the GK actions and shot situations. The most frequently observed action after preparatory motion was diving; however, no significant results were observed, indicating that this action was used more frequently in specific shot situations. Stepping and diving without preparatory motion were significantly more frequent than expected for shots resulting from tackles. Blocking occurred significantly more frequently than expected for shots resulting from loose balls. Responses to a second

attack were significantly more frequent than expected for shots resulting from other situations. Watching was significantly more frequent than expected for shots resulting from crosses and passes ($\chi^2 = 164.86$, $p < 0.001$, Cramer's $V = 0.252$).

Table 7. On-target shots categorized by the GK actions and shot situations.

GK's motion $\times$ Shot situation	B	C	I	L	P	T	O
1. Diving after preparatory motion	12 (9.2)	37 (29.8)	0 (0.4)	15 (19.1)	86 (85.4)	0 (1.5)	9 (13.6)
Adjusted residual	1.2	1.8	-0.8	-1.3	0.1	-1.5	-1.6
2. Stepping and diving after preparatory motion	1 (0.6)	0 (1.9)	0 (0.0)	0 (1.2)	6 (5.4)	1 (0.1)	2 (0.9)
Adjusted residual	0.6	-1.5	-0.2	-1.2	0.4	3.0*	1.3
3. Stepping and diving without preparatory motion	0 (0.3)	1 (0.9)	0 (0.0)	0 (0.6)	4 (2.7)	0 (0.0)	0 (0.4)
Adjusted residual	-0.6	0.1	-0.1	-0.8	1.2	-0.2	-0.7
4. Diving only	0 (0.5)	2 (1.5)	0 (0.0)	1 (1.0)	5 (4.3)	0 (0.1)	0 (0.7)
Adjusted residual	-0.7	0.5	-0.1	0	0.5	-0.3	-0.9
5. Catching	4 (6.0)	14 (19.5)	1 (0.2)	13 (12.5)	64 (55.9)	0 (1.0)	8 (8.9)
Adjusted residual	-1	-1.6	1.8	0.2	1.8	-1.1	-0.4
6. Parrying	2 (2.0)	4 (6.6)	0 (0.1)	3 (4.2)	23 (18.8)	1 (0.3)	2 (3.0)
Adjusted residual	0	-1.2	-0.3	-0.7	1.5	1.2	-0.6
7. Blocking	4 (3.6)	8 (11.8)	0 (0.0)	13 (7.6)	33 (33.8)	1 (0.6)	4 (5.4)
Adjusted residual	0.2	-1.3	-0.4	2.3*	-0.2	0.6	-0.7
8. Responding to a second attack	0 (0.7)	0 (2.3)	0 (0.0)	1 (1.4)	0 (6.4)	0 (0.1)	11 (1.0)
Adjusted residual	-0.9	-1.7	-0.2	-0.4	-3.8*	-0.3	10.4*
9. Watching	2 (2.1)	15 (6.8)	0 (0.1)	6 (4.3)	11 (19.3)	1 (0.3)	1 (3.1)
Adjusted residual	-0.1	3.7*	-0.3	0.9	-2.9*	1.2	-1.3
statistical result	$\chi^2 = 164.86$	df = 48	$p < 0.001$	Cramer's $V = 0.252$			

B: Ball progression, C: Cross, I: Intercept, L: Loose ball, P: Pass, T: Tackle, O: Other

Discussion

Because the variables measured in this study were categorical, κ coefficients were calculated to assess the agreement between the two observers' measurements. The results indicated almost perfect or substantial agreement (Landis & Koch, 1977). A high κ coefficient of 0.94 was reported in a study that involved detailed classification and measurement of diving motions, indicating a higher level of agreement than in the present study (Numazu et al., 2017). The higher agreement in the previous study can be attributed to the fact that their research analyzed footage captured by a video camera at a match venue rather than televised footage (Numazu et al., 2017). Additionally, measuring GK actions using broadcast footage can have several limitations, such as difficulty in accurately distinguishing changes in the GK's stance width because of the camera angle, even when the GK is visible during shot scenes, thereby limiting the ability to distinguish GK movements in detail using televised footage (Matsukura & Hirashima, 2020). However, the agreement level did not significantly decrease despite the more challenging conditions for accurately distinguishing diving motions in this study compared with prior research (Numazu et al., 2017). Consequently, considering the agreement levels for both the shot area and the frequency of ball touches, the analysis items examined in this study demonstrated sufficient objectivity for research purposes.

GKs are more likely to fail in shot-stopping when they have less time to react (Hirashima et al., 2014; Hirashima et al., 2018; Matsukura & Hirashima, 2020). In soccer, the primary objective of an attack is to score goals and increase the number of shots taken near the center of the goal, where GKs are more prone to failure, thereby increasing the likelihood of scoring. Most shots occur within the penalty area, not just in dangerous areas (Michailidis et al., 2013; Njororai, 2013; Yiannakos & Armatas, 2004). This study hypothesized that the location of a shot influences the frequency of the preceding play and the body parts used for the shot. The results indicated significant differences between the observed and expected frequencies of these variables, supporting

this hypothesis. Specifically, the number of goals in areas AN and BN were significantly higher than expected. The observed values exceeded the expected values for AN; however, the difference was not significant in a previous study focusing on the 2018 World Cup (Matsukura & Hirashima, 2020). Therefore, a higher-than-expected number of goals in AN may be a distinctive feature of the 2022 World Cup. Additionally, the dangerous areas identified by Matsukura and Hirashima (2020) were AN and BN in this study, where the number of goals exceeded the expected values. The similarity of these findings to those of previous studies could be attributed to the fact that when a shot is taken from a location farther from the goal, such as in the far area, the GK has more time to react, even if the shot speed is the same, than when a shot is taken from the near area. Therefore, similar to in previous research (Matsukura & Hirashima, 2020), areas AN and BN can be considered dangerous areas where GKs are frequently challenged by difficult shot-stopping situations.

In AN, the number of shots from crosses was significantly higher than expected when investigating the characteristics of the 234 shots from dangerous areas in the 2022 World Cup. “Watching,” an action recorded only when a goal is conceded, occurred significantly more frequently than expected for shots from crosses, and the number of “watching” occurrences in dangerous areas exceeded the predicted value. Executing an accurate shot becomes challenging for the shooter when a player receiving the ball takes a one-touch shot. Therefore, the GK must adjust their position according to the ball's movement and respond to the shot, making them less likely to achieve shot-stopping (Hirashima et al., 2014; Matsukura & Hirashima, 2020). Therefore, the frequent occurrence of one-touch shots from crosses presents a challenging situation for GKs in the dangerous areas of the 2022 World Cup, particularly in AN, making it difficult to stop the shots, which often result in goals. The ball moves from near the touchline to an area in front of the goal when a cross is used in offensive play. The GK must adjust their position according to the ball's movement and perform preparatory and diving actions in time with the shot. The frequent occurrence of “watching” in response to crosses may be attributed to the GK failing to respond effectively if it is assumed that the GK's failure to stop the shot was because of their inability to react appropriately. However, although the frequency of shots from passes was lower than expected or approximately the same, passes were the most common method of attack in dangerous areas, accounting for 44.8% of the attacks. In dangerous areas such as the central area near the goal, defense is often vital to prevent scoring, leaving the shooter with limited time and space to control the ball before shooting. As a result, 74.8% of the shots in dangerous areas were likely to be taken with one touch. Furthermore, the GK must adjust their position based on the movement of the ball, even for shots from passes. Therefore, although the frequency of shots from passes in dangerous areas was not as high as expected, shots from passes, such as those from crosses, posed a significant challenge for GKs and were likely to result in achieving goals, which may explain their frequent occurrence.

The shooter controls the ball when they touch it multiple times before taking a shot. Directing a one-touch shot is challenging (Hirashima et al., 2014; Matsukura & Hirashima, 2020); therefore, shooters have more opportunities to aim for controlled shots in areas AF, BF, and CF than in dangerous areas. The number of shots from passes was significantly higher than expected, and the number of shots taken with two or more touches was also significantly higher than predicted when considering the characteristics of shots taken outside the dangerous areas, which included AF, BF, and CF. However, these areas had significantly higher savings than expected. Focusing on the role of the GK in these shot scenarios, GKs adjust the timing of their movements by observing the shooter's actions (Savelsbergh et al., 2002; Numazu et al., 2022). Thus, one characteristic of shots from areas AF, BF, and CF is the reduced time constraints for the GK, allowing for easier timing adjustments. This makes these shots easier to save, even though it may be easier for the shooter to aim for a controlled shot compared to more dangerous areas.

Additionally, the number of shots from the ball progression was significantly higher in areas CN and CF than expected (Table 3). While penetrating these areas brings the player closer to the opponent's goal (Matsukura & Hirashima, 2024), these areas are closer to the touchline or goal line, which narrows the shooting angles and the area the GK needs to defend compared to areas directly in front of the goal. Most (80%, 20 of 25) of the attacks involving ball progression occurred outside dangerous areas, and 88% (22 of 25) were saved by the GK. Moreover, penetrating dangerous areas through ball progression is challenging in areas AN and BN near the center of the goal, where defense is often vital for preventing scoring. Therefore, as indicated by the results of this study, a characteristic of shots from areas such as CN and CF, which are outside dangerous areas and relatively far from the goal, is their higher frequency, often resulting from ball progression.

Dangerous areas impose significant time constraints on the shooter and the GK, making it challenging to execute accurate shots and effective shot-stopping. In addition, when dealing with passes, the GK must adjust their position according to the ball movement. In this study, we hypothesized that GKs would dive more frequently after preparatory motion to respond in areas with a high frequency of shots, such as dangerous areas. Although the results did not show a significant difference from the expected values, diving after preparatory motion was used with a high frequency across all areas, suggesting that the hypothesis was partially supported. In contrast, in AN, the frequencies of stepping and diving without preparatory motion and blocking were significantly higher than expected. These characteristics may have influenced the increased frequency of blocking in dangerous areas. While the frequency of blocking was approximately the same as expected, 52.3% (33 out of 63) of the shots blocked by the GK originated from passes. Therefore, in AN, which is near the center

of the goal, the GKs may have prioritized ensuring that the shot was stopped by approaching the shooter and narrowing the area they needed to defend, leading to a higher frequency of blocking.

Stepping and diving without preparatory motion may occur when GKs fail to adjust their position in time for attacks involving ball movements, such as crosses or passes (Matsukura & Hirashima, 2020). This possibility is also suggested by the frequent occurrence of “watching” in dangerous areas and during crosses or passes, which can be attributed to similar reasons. Therefore, while GKs frequently use diving after preparatory motion to respond to incoming shots, blocking is more effective in dangerous areas to prevent the shot, thus leading to a higher frequency. Moreover, because of significant time and spatial constraints, GKs may not always have the opportunity to execute preparatory motions in near areas, which could explain why diving was observed exclusively in these areas.

Regarding GK movements in response to shots outside dangerous areas, the frequency of stepping and diving after preparatory motion was significantly higher than expected in AF and BF. The characteristics of these shots can explain this result. Shots from these areas likely allowed the GK to adjust their position, making it easier to move into a position where they could catch the ball or dive.

Additionally, the frequency of blocking was significantly higher than expected in CN. Attacks in CN often involved ball progression or passing. Because these shots are closer to the goal, blocking and diving become an adequate response, which likely leads to an increased frequency. These findings align with those of Matsukura et al. (2024), who stated that GKs choose and perform the most effective actions to reach the ball based on the time and spatial constraints they face. The results of this study suggest that situations with time and spatial constraints can be understood as a combination of shot area and situation.

Based on the results of this study, the following training designs for GKs can be considered: For training that aims to increase the occurrence of diving after preparatory motion and blocking, practice scenarios must be created that reduce time and spatial constraints on the GK. Therefore, creating situations in which crosses or passes deliver the ball is recommended in dangerous areas, leading to one-touch shots, particularly in AN, where shots from crosses should be emphasized. GKs should proactively approach the ball to prevent shooting opportunities from arising, in addition to attempting shot-stopping in AN, where shot-stopping is often challenging. For blocking, practical training could involve simulating situations in which the opponent has penetrated deep into the GK's territory, such as in CN or CF, with an emphasis on shots resulting from ball progression or passes.

To increase the frequency of stepping and diving after preparatory motion and catching, practice scenarios that impose greater time and spatial constraints on the goalkeeper should be created. Specifically, situations should be simulated outside the critical areas, particularly in more distant regions, where passes lead to shots that require two or more touches. This approach creates scenarios distinct from those in high-risk areas. This study classified and measured actions such as stepping and diving without preparatory motion, diving only, responses to second attacks, and watching. However, stepping and diving without preparatory motion and diving are actions that may occur when the GK cannot respond in time to a shot, whereas responses to secondary attacks and watching are situations that are difficult to simulate during training. Therefore, this study did not propose specific training designs based on these categories.

Conclusions

This study measured and analyzed shot situations according to location, shot situation, and the number of ball touches in combination with GK actions to examine the relationship between shot situations and GK actions. Even in the 2022 FIFA World Cup in Qatar tournament, areas near the center and close to the goal were dangerous areas where shot-stopping was difficult for GKs. In areas such as AN, near the center of the goal, and close to the goal, a high frequency of one-touch shots from the crosses was observed. Conversely, in the far areas, where the distance to the goal increased, a higher frequency of shots was observed from passes with two or more touches.

The diving action most frequently performed by GKs was diving after preparatory motion. However, as the time and spatial constraints for responding to shots increased, GKs also showed a higher frequency of blocking to ensure shot-stopping. However, a higher frequency of catching, stepping, and diving after preparatory motion was observed when the time and spatial constraints for responding to shots decreased. This study also proposes specific training plans based on the results, which is a distinctive feature of this study compared to prior research. Future research could further improve these strategies by incorporating additional factors, such as the specific foot used for shooting and the precise placement of the shot on the goal.

However, this study did not consider which foot was used for the shot or the exact location of the shot at the goal. Clarifying these aspects could contribute to more detailed training plans, such as identifying the types of shots that must be practiced.

Conflicts of interest

The authors declare no conflict of interest.

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