

A STUDY ON THE OPTIMAL DEFENSE POSITION OF HANDBALL GOALKEEPER: FACING A FORWARD JUMP SHOT MADE FROM 9M

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The purpose of the study was to derive an optimal defense position for goalkeepers through calculating ideal defense area and actual defense area when blocking forward jump shots from 9 m distance. A total of 9 men's handball matches were captured with 4 digital video cameras from the 94th Korea National Sports Festival with consent from the Korea Handball Federation. Video clips with 78 forward jump shots from 9 m distance which included the whole movements of goalkeeper were analyzed. The ball's speed in the forward jump shot, release point of the ball, goalkeeper's defensive stance, and defensive position were analyzed. The actual defense position of goalkeeper was 1.10 ± 0.37 m and the optimal defense position calculated through the movements of goalkeeper was 1.45 m from the goal line.

KEY WORDS: goalkeeper, handball, optimal defense position.

INTRODUCTION: In various sports, including handball, soccer, field hockey, ice hockey, lacrosse, and water polo, a player is designated as a goalkeeper, who is the rearmost defender in charge of preventing the opponent from scoring. Although each player who participates in a match plays an important role, unlike players in other position, a goalkeeper does not have any teammates in the backfield. In other words, a mistake by a field player can be overcome by the help of the other teammates, but a mistake by a goalkeeper directly leads to conceding a goal, which directly affects the outcome of the match. Therefore, a goalkeeper can be viewed more important than players in other positions as they should not commit any mistakes and have to be more responsible.

Assuming that a goalkeeper's left-right reaction speed is the same, the goalkeeper should undoubtedly be positioned exactly in the middle of the defensive range relative to the ball in flight. However, it is not easy to determine how much in front of the goal line the goalkeeper should stand. Existing instructional material on handball states that handball goalkeepers should always position themselves about one step (0.75 m) in front of the goal line, to reduce the angle of the shot (Clanton & Dwight, 1996; Institute of Sport Science, 1984; Rho, 2010). According to handball coaches and players, the defensive position of a goalkeeper is determined by the collective experiences of the coaches and players. There have been no studies regarding the issue of defensive position of goalkeeper. Although the impact of a goalkeeper's defensive position on his/her blocking rate has not yet been clearly identified, if the blocking rate changes according to a goalkeeper's defensive position, it is important to identify that "optimal defensive position" that can improve the goalkeeper's blocking rate.

Analysis of the results from the 2012 SK Handball Korea League men's matches found that among a total of 2,183 shots, approximately 25% were forward shots made from 9 m (Korea Handball Federation, 2012). Therefore, the purpose of the study was to examine an optimal defence position for goalkeepers through calculating ideal defense area (IDA) and actual defence area (ADA) when blocking forward jump shots from 9 m distance. The present study limits its investigation only to situations in which the goalkeeper successfully defended forward jump shots made from 9 m during matches.

METHODS: The present study filmed a total of 9 men's handball matches from the 94th National Sports Festival (South Korea) and analysed 13 goalkeepers (Age: 24.5 ± 5.2 years, Height: 185.7 ± 2.7 cm, Weight: 83.3 ± 7.5 kg) performance.

4 digital video cameras (Sony HDR-CX560, Japan) were used to capture the movements of the goalkeeper. The cameras were set up approximately 15 m high on the railings in the stands, at about a 45° angle, to capture all goalkeepers and shooters. The frame rate and

shutter speed were set to 30 frames/sec (60 fields/sec) and 1/250 sec, respectively. 4 control objects, 1 m×1 m×3 m in size, were placed and shot prior to the matches.

The ball's speed in the forward jump shot made from 9 m, release position of the ball, defensive position, goalkeeper's performance were derived. The videos were analysed using video editing (Sony Vegas pro 9.0, Japan), video analysis programs (Kwon 3D 3.01, Korea) and Excel 2010 (Microsoft Inc., USA).

A total of 16 points (11 points for the hands, elbows, shoulders, head, knees, and feet; 4 points for the corners of the goal post and 1 point for the ball) were digitized and referenced. When digitizing, reconstruction errors are 0.808 cm and 0.693 cm at each court. When calculating the 3D coordinates, the Butterworth 2nd-order low-pass filter was used to with a cut-off frequency of 5 Hz.

The release position of the ball, speed of the ball in the forward jump shot made from 9 m, goalkeeper's actual defence position, ideal defence area (IDA), and actual defence area (ADA) were derived using the positional information on the end segments, goal frame, and ball obtained from the video analysis. Finally, the optimal defensive position was obtained through the ratio of the ADA and IDA, termed as the actual defence area ratio (ADA ratio).

A goalkeeper defence position was defined as the position where he/she assumes a defensive stance to block the shot. It was expressed as the distance from the goal line to the goalkeeper's defensive position (relative to the heel). The IDA referred to the range of area that the goalkeeper must actually defend according to the position, the direction of shots, and his/her defensive position (Figure 1a). IDA was calculated from the equation 1.

$$IDA = \left\{ 2m + (h_{ball} - 2m) \times \frac{d_{GK}}{d_{ball}} \right\} \times \left\{ 3m \times \frac{d_{ball} - d_{GK}}{d_{ball}} \right\} \quad (1)$$

(IDA: Ideal defence area, d_{GK} : goalkeeper defense position, h_{ball} : ball height, d_{ball} : distance from the center of the goal line to the ball)

The ADA quantifies the range of area in which a goalkeeper is able to block the ball with his/her limbs within the time frame from the ball-release up till it reaches the goalkeeper.

To obtain the ADA, the area of a polygon formed by connecting all of the goalkeeper's bodily end segments (head, hands, and legs), from the movements in various directions during the actions of blocking on the frontal plane, was calculated (Figure 1b).

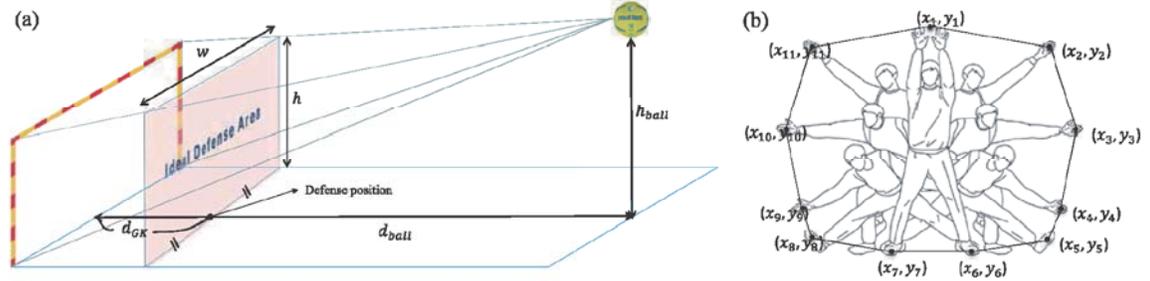


Figure 1. (a) A visual depiction for calculating the ideal defence area, (b) The reference points used for calculating the ideal defence area

The area of the polygon formed by connecting Point(x_1, y_1), Point(x_2, y_2), Point(x_3, y_3), Point(x_4, y_4), Point(x_5, y_5), Point(x_6, y_6), Point(x_7, y_7), Point(x_8, y_8), Point(x_9, y_9), Point(x_{10}, y_{10}), and Point(x_{11}, y_{11}) in Figure 1b was calculated by the formula:

$$ADA = \frac{1}{2} \left\{ \sum_{i=1}^{10} (x_i y_{i+1} - y_i x_{i+1}) + x_{11} y_1 - y_{11} x_1 \right\} \quad (2)$$

(ADA: Actual defense area)

A goalkeeper's optimal defensive position refers to the defensive position with the highest probability of blocking the shot when all conditions, such as shot position, speed of the ball, and goalkeeper's reaction are the same. The optimal defensive position was defined as the point with the highest ratio between IDA and ADA.

Independent t-test was performed to determine the defense position of goalkeeper between the given values in instructional material and while blocking forward jump shots made from a distance of 9 meters. In statistical analyses, α was set to 0.05 and statistical analyses was conducted using IBM SPSS Statistics 23 for Windows.

RESULTS: As a result of the forward jump shots made from 9 m, the position of the ball at the time of being released from the shooter's hand, relative to the center of the goal line, was 8.41 ± 0.9 m in front, 0.04 ± 2.0 m to the left, and 2.36 ± 0.28 m high, while the average speed of the ball until it reached the goalkeeper was $23.53 (\pm 1.91)$ m/s. The defense position of the goalkeeper in instructional material and in actuality are different while blocking forward jump shots made from a distance of 9 meters. The goalkeeper's defense position was 1.10 ± 0.37 m in front and 0.01 ± 0.39 m to the left with reference to the center of the goal line. These results were significantly different than goalkeeper's defense position stated in instructional material ($t=4.455, p<.001$).

To calculate the goalkeeper's optimal defensive position, the IDA, ADA, and ADA ratio according to the goalkeeper's defensive position were derived. When facing forward jump shots made from 9 m, the IDA, ADA, and ADA ratio for the goalkeeper positioned 0.1 m beyond the goal line were 5.940 m^2 , 3.151 m^2 , and 53%, respectively, and the same were 4.024 m^2 , 2.188 m^2 , and 54.4%, respectively, when the goalkeeper was positioned at 3.12 m beyond the goal line (Table 1). The defensive position with the highest ADA ratio of 60.2% was at 1.61 m from the goal line.

Table 1. The ideal defense area (IDA), actual defense area (ADA), and actual defense area ratio (ADA ratio) according to the defensive position of a goalkeeper facing jump shots made from 9 m

Defensive position (m)	Defense area		IDA (m ²)	ADA (m ²)	ADA ratio (%)
	Width (m)	Height (m)			
0.10	2.963	2.004	5.94	3.15	53.0
0.48	2.829	2.021	5.72	3.28	57.3
0.86	2.694	2.037	5.49	3.22	58.7
1.24	2.559	2.053	5.25	3.15	59.9
1.61	2.424	2.069	5.02	3.02	60.2
1.99	2.290	2.085	4.78	2.83	59.3
2.37	2.155	2.101	4.53	2.63	58.1
2.75	2.020	2.118	4.28	2.41	56.4
3.12	1.886	2.134	4.02	2.19	54.4

Note. Defensive position, IDA, Ideal Defense Area; ADA, Actual Defense Area; ADA ratio, Actual Defense Area ratio;

*Position of the jump shot made from 9 m: 8.41 m from the center of the goal line, height 2.36 m

The maximum ADA ratio obtained from the trend line was 60.2%, which was shown to be at defensive position of 1.45 m ~ 1.61 m from the goal line (Figure 2). Therefore, when blocking forward jump shots made from 9 m, handball goalkeepers need to move forward by 0.35 m ~ 0.51 m, towards the shooter, as compared to their current actual defensive position of 1.10 m

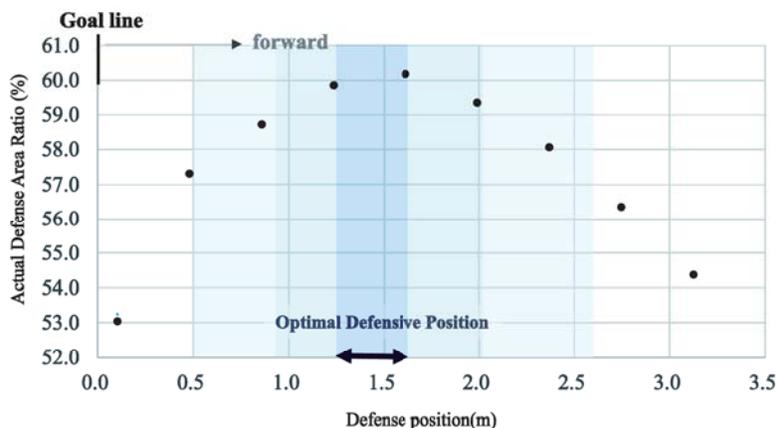


Figure 2. The actual defense area ratio according to the defensive position of the goal keeper while blocking forward jump shots made from 9 m (distance: 8.41 m, height: 2.46 m, shot speed: 23.53 m/s)

DISCUSSION: In the current study, the optimal defensive position that was calculated from the actual positions of jump shots made from 9 m, speed of the ball, and goalkeepers' movements, was in between 1.45 m and 1.61 m. The optimal defensive position in the current study corresponds to twice the distance suggested in the existing manuals "one step from the goal line (0.75 m)" and represents a distance that required goalkeepers to move another 0.35 m in the direction of the shooter, as compared to the actual defensive position of 1.10 m shown by goalkeepers in the match videos examined in the present study. When goalkeepers defend at the optimal defensive position (1.45 m ~ 1.61m) instead of at their actual defensive position (1.10 m), the ADA ratio increased by approximately 0.5%. This means that when a goalkeeper defended in optimal defensive position (1.45 m ~ 1.61 m) from the goal line rather than actual defensive position (1.10 m), he/she was able to cover more area, equivalent to cross-sectional area of one handball. Further, the ADA ratio increased by 1.7 % (cross-sectional area of 4 handballs) compared to when blocking at "one step from the goal line," as suggested in the existing manuals.

CONCLUSION: The actual defense position of goalkeeper was 1.10 ± 0.37 m and the optimal defense position calculated through the movements of goalkeeper was 1.45 m from the goal line. The top class handball goalkeeper's actual/optimal defense position can be used as a reference for players learning handball goalkeeping, as well as creating new standards that will help improve their performance. However, these standards may be restricted to Korean players with a similar body shape and conditioning with different standards being presented according to a change in various conditions (the position of the shot, the ball speed, the goalkeepers' physical condition, etc.).

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