Paper : Game Analysis

Development of Criterion-Referenced Measurement Items of Penetration Pass Play in Soccer Game

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The purpose of this study was to develop criterion-referenced measurement items of penetration pass play in soccer games. Cause and effect analysis with the Delphi method was applied to construct a qualitative causal structure, measurement items, and achievement criteria of penetration pass play in soccer games. Structural equation modeling (SEM) was applied to analyze a second-order factor structured model of the penetration pass play. Item response theory (IRT) with the 2-parameter logistic model (2PLM) was applied to analyze the item and the test characteristics of penetration pass play items. The first-order factors of penetration pass skill in soccer consisted of through pass, positioning, unbalancing DFL (Defense line), and breaking DFL skills. The 16 items measuring penetration pass play showed construct validity. The item unidimensionality, goodness-of-fit to the item characteristic curve (ICC), invariance of estimated parameters and ability value, test reliability, validity and goodness-of-fit to the ICC were examined using IRT with 2PLM. The value of the estimated ability of the successful penetration pass group in the soccer game was 0.30 ± 0.79, which was significantly higher than the -0.45 ± 0.73 reported for the unsuccessful pass group. These results indicate that the criterion-referenced measurement items of penetration pass play in soccer games are valid.

Keywords: criterion-referenced measurement, item response theory, second-order factor structure, qualitative causal structure

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1. Introduction

Pappalardo et al. (2019) reported that the pass is the most frequently occurring play in soccer games, appearing on average approximately 700-800 times per game. Among the passes, penetrative passes, such as through and forward passes against the opponents' goal direction, are the most important in soccer games because they directly lead to scoring and shooting. Tenga et al. (2009) defined penetrative passes as "Passes toward the opponent's goal past opponent player(s) while maintaining control over the ball and otherwise for non-penetrative passes." Tenga et al. (2010) applied logistic regression analysis and found that penetrative passes have a higher odds ratio for increasing the probability of scoring a goal. These studies indicate that the penetration pass contributes to the attacking success in soccer games.

Most evaluations of penetration passes in soccer coaching depend on the experience of coaches or players. Suzuki (2005) and Matsuoka et al. (2020) extracted the qualitative causal structure of soccer skills that soccer experts see as tacit knowledge to measure attacking and defending play from soccer game performance data. By applying the same method, it is necessary and feasible to develop a method to measure the penetration pass play achieved in soccer games.

However, studies related to pass play analysis have mainly focused on measuring the technical skills of pass play by skill tests, on misalignment with the target owing to instep kicks (Ohta and Hattori, 1983), or on the analysis of perceptual and cognitive structures (Natsuhara et al., 2015; Terada and Sano, 2017). Therefore, tactical skill factors involved in penetration pass play are unresolved.

In recent years, the development of sports data technology has led to the development of pass

play analysis using machine learning. Brooks et al. (2016) analyzed the passes leading to a high shooting probability by using machine learning to pass event data and reported that the pass play of Cristiano Ronaldo and Lionel Messi had high pass values, suggesting that this may lead to player evaluation. In the same study, the pass play of players who are passers was evaluated. However, it was insufficient as data for coaching because the player information related to the pass play, but the response of the receiver of the pass was not measured. As for the studies on passing tactics that measured the information of supporting players and defending players, studies have estimated the probability of a successful pass by defining the dominant area of players (Taki and Hasegawa, 1998), studies that developed a model of pass behavior of passers by utilizing the dominant area of players (Sekozawa and Omori, 2014), and studies that constructed measurement items of pass plays that take into account the pressure of the opposing DF (a defender) were undertaken (Wakita and Murota, 2017). These studies analyzed the value of space and pass play in consideration of player interactions by using the dominance domain. However, to be used in data-driven coaching, it is necessary to construct measurement items that provides a basis of the causal relationship of penetration pass play and the criteria of successful penetration pass play.

To construct measurement items that provide the basis for the causal structure and achievement criteria of penetration pass play, factor analysis and item response theory analysis were useful strategy to identify valid measurement items. In previous studies, causal structure of defensive play and offensive play were shown by the exploratory factor analysis or confirmatory factor analysis (Suzuki, 2005; Matsuoka et al., 2020; Matsuoka et al., 2022). Matsuoka et al. (2020) constructed the criterion-referenced measurement items of soccer defensive tactical play by using the both of the factor analysis and item response theory. In their study, they found factor structure by the confirmatory factor analysis and selected the items with factor validity. Then they applied the item response theory to investigate the measurement items which enable to use as criterion-reference measurement for soccer defensive tactical play. Thus, by applying the test theory of criterion-referenced measurement, it is possible to construct items to measure the achievement of penetration pass play from game performance.

The purpose of this study was to develop criterion-referenced measurement items of penetration pass play in soccer games.

2. Method

2.1. Research procedures

Research procedures, scaling procedure, included three steps in this study. The first step was to construct the qualitative causal structure, measurement items, and achievement criteria of penetration pass play in soccer games by applying cause-and-effect analysis with the Delphi method. The second step was to analyze skill factors of penetration pass play in soccer games by exploratory factor analysis and confirmatory factor analysis. Finally, to develop criterion-referenced measurement items of penetration pass play in soccer game, item response theory (IRT) with 2 parameter-logistic model (2PLM), was applied to select valid items.

2.2. Samples

The penetration pass plays were corrected from the 2018 World Cup in Russia (4 plays from two games), 2019-20 UEFA Champions League (17 plays from eight games), 2019-20 UEFA Europa League (1 play from a game), 2019-20 Premier League (15 plays from seven games), 2019-20 La Liga (3 plays from three games), 2020 J1 League (36 plays from twenty-three games), and 2020 Kanto University Soccer First Division (24 plays from a game), totaling 100 plays from forty-five games. In order to develop a content-relevant and criterion-referenced items, samples were extracted from a population with a wide range of skill levels, from penetration pass play at the professional league level (the World Cup, the UCL, and the J-League) to penetration pass play at the university soccer level (the Kanto University Soccer League).

The definition of the penetration pass plays in this study were followed by Tenga et al. (2009) as “Passes toward the opponent’s goal past opponent player(s) while maintaining control over the ball and otherwise for non-penetrative passes.” A successful pass was defined as a penetrative pass play leading to the shot or shot assist after the player receive the pass, and an unsuccessful pass was defined as any other case. Number of successful passes were 60 passes and

unsuccessful passes were 40. Match videos were downloaded from Wyscout (Wyscout Spa, Italy). The use of data was reviewed and approved by the Research Ethics Committee of Institute of Health and Sport Sciences, University of Tsukuba (Project No. 021-36).

2.3. Construction of measurement items

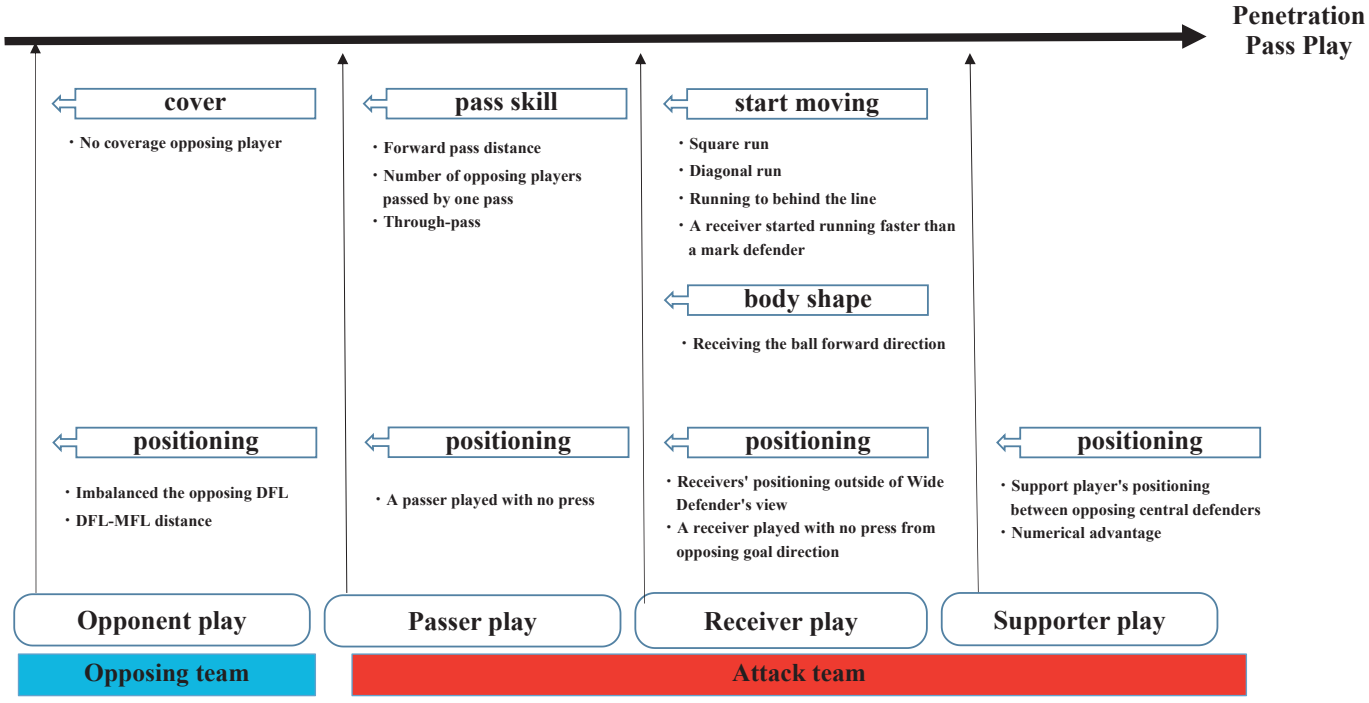
In accordance with Matsuoka et al. (2020), criterion-referenced measurement items of penetration pass play in soccer games were constructed. Cause-and-effect analysis with the Delphi method of qualitative analysis was applied to extract the causal structure, criterion-referenced measurement items, and achievement criteria of penetration pass play, which were seen as tacit knowledge by soccer experts. Four soccer experts were included in the study: two soccer players who had played for the Japanese national team and overseas clubs, one coach with more than 10 years of coaching experience, and one graduate student who was active as a soccer player and engaged in sports science research. They were experienced in using a qualitative analysis method. The subjects were interviewed individually, and based on the extracted information, the researcher organized this into a characteristic factor diagram and gave this back to the soccer experts. The procedure was repeated until all soccer experts agreed on the results.

The penetration pass play qualitative causal structure consisted of four plays, namely, "passer play," "receiver play," "supporter play," and "opponent play", and their corresponding eight sub-plays. Based on the cause-and-effect diagram (fishbone diagram), 16 penetration pass plays were constructed (**Figure 1**).

2.4. Measurement method

Sixteen measurement items and achievement criteria were constructed based on the qualitative causal structure of the penetration pass play. Fourteen of sixteen items were measured on a binary scale (1 or 0). If the item was satisfied with the achievement criteria (**Table 1**), it was recorded as 1 (the item was achieved), in other case it was recorded as 0 (not achieved). For example, v4 Through pass achieved 61 times of 100 plays (**Table 2**). As two of the items, v2 and v15, are ratio scale items, the achievement criteria are the branching values obtained from the decision tree analysis of the categorical classification

Figure 1 Cause and effect diagram (fishbone diagram) of penetration pass play in soccer games



Notes: *Definition of forward pass was follow by Fernandez-Navarro et al. (2016). **Definition of through-pass was followed by Stat Perfom (https://www.statsperform.com/opta-event-definitions/) as "a pass splitting the defence for a team-mate to run on to."

tree model, with each item as an independent variable and the successful pass as a dependent variable. The achievement criterion of the v2 Forward pass distance obtained from the decision tree analysis was >39.155 m, and that of the v15 DFL (Defense line) –MFL (Midfield line) distance was <6.66 m (**Table 1**). Thus, in the two items, if the measurement values of the item are satisfied with the branch values, they were receded as 1 (the item was achieved). For example, the v2 Forward pass distance was 39.155 m or more in 30 of 100 plays and was an achievement (**Table 2**).

According to the penetration pass play items and achievement criteria, the author measured the achievement binary data of the penetration pass play items from the video clips.

2.5. Statistical Analysis

To analyze the construct validity of soccer penetration pass play, exploratory factor analysis (EFA) and structural equation modeling (SEM) were applied to analyze a second-order factor structure model of the penetration pass play items. Exploratory factor analysis was conducted using a tetrachoric correlation matrix among the penetration pass play items. Factors with eigenvalues ≥1.0 were extracted using the principal factor solution method. Each factor name was defined by referring to items with factor loadings of ≥0.3 in the factor pattern matrix after promax rotation. Because there were correlations among the factors, structural equation modeling was applied to analyze the second-order factor structure model of the penetration pass play. The diagonal weighted least-squares method was used to estimate the parameters from the tetrachoric correlation matrix (Rosseel, 2012). The overall model fit was determined using the goodness-of-fit indices TLI, CFI, RMSEA, SRMR, χ^2value, and significance probability (p). In accordance with Browne and Cudeck (1993) and Kline (2016), the model with CFI and TLI > 0.9 and RMSEA < 0.05 was judged to be a good fit. The factors estimated from the confirmatory factor analysis and confirmatory factor structure analysis of the penetration pass play items were the penetration pass skill factors involved in penetration pass play in soccer games.

In accordance with Ando et al. (2018), unidimensionality, goodness-of-fit of items to a two-parameter-logistic model, invariance of item parameters and ability values, test reliability,

Table 1 Measurement items of penetration pass play in soccer games

Team	Play	Skill	ID	Item	Timing of measurement	Achievement criteria
Attack team	Passer play	positioning	v1	A passer played with no press	when passer passing	The passer played with no opposing defenders.
		pass skill	v2	Forward pass distance	when receiver trapping	The forward pass* distance was 39.155m or more.
			v3	Number of opposing players passed by one pass	when receiver trapping	The Number of opposing players passed by one pass was 6 or more.
			v4	Through-pass	when receiver trapping	The pass was the Through-pass**.
	Receiver play	positioning	v5	Receivers' positioning outside of Wide Defender's view	when passer passing	The receiver was in a position outside of opposing Wide Defender's view.
			v6	A receiver played with no press from opposing goal direction	when receiver trapping	The receiver played with no opposing defenders from opposing goal direction.
		start moving	v7	Square run	when passer passing	The receiver did square run before receiving the pass so as not to be offside.
			v8	Diagonal run	when passer passing	The receiver run diagonally to receive the pass.
			v9	Running to behind the line	when passer passing	The receiver run to behind the opposing defense line from MFL.
			v10	A receiver started running faster than a mark defender	when passer passing	The receiver started running faster than a mark defender.
		body shape	v11	Receiving the ball forward direction	when receiver trapping	The receiver received the ball forward direction.
	Supporter play	positioning	v12	Support player's positioning between opposing central defenders	when passer passing	A support player was in a position between opposing Central Defenders.
			v13	Numerical advantage	when receiver trapping	The situation on the opponent's goal side over the receiver was Numerical advantage.
Opposing team	Opponent play	positioning	v14	Imbalanced the opposing DFL	when passer passing	The forward distance between the opponent defenders (Imbalanced the opposing DFL) was 2.5 m or more.
			v15	DFL-MFL distance	when passer passing	The distance between the opponent's defense line and midfield line was 6.66m or more.
		cover	v16	No coverage opposing player	when receiver trapping	There was no coverage of opposing player.

Notes: *Definition of forward pass was follow by Fernandez-Navarro et al. (2016). **Definition of through-pass was followed by Stat Perfom (https://www.statsperform.com/opta-event-definitions/) as "a pass splitting the defence for a team-mate to run on to."

validity, and fit were analyzed. Following Watanabe and Noguchi (1999), Toyoda (2002), and Aoyagi (2005), exploratory factor analysis was conducted on the tetrachoric correlation matrix between the items to analyze the unidimensionality of the items. The eigenvalues were scree analyzed, and the total variance explanatory rate of the first eigenvalue was checked. Items with first factor loadings < 0.0, which were obtained from confirmatory factor analysis using the principal factor solution method, were deleted individually. The exploratory factor analysis was repeated until all factor loadings reached positive values.

Item response theory (IRT) analysis of the two-parameter logistic model (2PLM) was applied to estimate the item parameters and ability values using the maximum likelihood estimation method. Items outside the range of difficulty|5.0| and items with discrimination < 0.2 were deleted. χ^2 tests were applied to analyze the goodness-of-fit of the items to the 2PLM. The invariance of item parameters and ability values was analyzed according to Hambleton et al. (1991). Invariance coefficients (Pearson's product-rate correlation coefficients) between item parameters estimated from the two separated samples by systematic random sampling were calculated. The invariance coefficients (Pearson's product-rate correlation coefficients) between the ability values estimated from the two separate items using the systematic random sampling method were calculated. The test reliability coefficients (ρ) were calculated from the test information I (θ). The range of ability values showing reliability coefficients of ≥0.7, was confirmed according to Nunnally (1978). The reliability coefficient of the test (ρ) is calculated using the following equation:

$$\rho = 1/(1+I(\theta)^{-1})$$

The criterion-related validity of the ability values for the test scores was analyzed. The goodness-of-fit of the test characteristic curve to the scatter plot of the test scores and ability values was visualized, and the goodness-of-fit of the test was analyzed. To analyze the validity of the criterion-referenced measurement test of penetration pass play, we tested the difference in mean ability values between the successful penetration pass and unsuccessful groups. The successful penetration pass groups were classified as goals, shots, and PA (penalty area) penetrations after a pass, whereas the others were classified as failures. A one-way analysis of variance of the between-subject factors was applied to confirm the validity of the criterion-referenced measurement test of the penetration pass play based on significant differences between the means of the ability values of the successful and unsuccessful groups.

Python version 3.7.6 and "scikit-learn" model package were used for the decision tree analysis, R version 3.5.3 Lavaan package was used for construct validity analysis, "psych package" was used for unidimensionality analysis, and ltm package was used for IRT analysis. IBM SPSS version 26.0.0.1 was used to analyze the validity of the criterion-referenced measurement test. The significance level was set at $p<0.05$.

3. Results

3.1. Skill structure

An exploratory factor analysis of the penetration pass play items revealed four factors that explained 78% of the total variance. The items that showed high factor loadings for the first factor were v2_Forward pass distance, v3_Number of opposing players passed by one pass, v1_A passer played with no press, v7_Square run, v4_Through pass, and v11_Receiving the ball forward direction. The first factor was interpreted as F1: Thorough pass skill. The items that showed high factor loadings for the second factor were v9_Running to behind the line, v12_Support player's positioning between opposing central defenders, v5_Receivers' positioning outside of Wide Defender's view, and v10_A receiver started running faster than a mark defender. The second factor was interpreted as F2: Positioning skill. The items that showed high factor loadings for the third factor were v14_Imbalanced the opposing DFL, v16_No coverage opposing player, and v13_Numerical advantage, which was interpreted as F3: Unbalancing DFL skill. The items that showed high factor loadings on the fourth factor were v6_A receiver played with no press from opposing goal direction, v8_Diagonal run and v15_DFL-MFL distance. The fourth factor was interpreted as F4: Breaking DFL skill. The correlation coefficient between the first and second factors was 0.44, and that between the first and fourth factors was 0.47, which was more than moderate.

Figure 2 shows the second-order factor structure

of the penetration pass play. Structural equation modeling was applied to analyze the second-order factor structure model, and it was confirmed that construct validity was satisfied for the 16 items. The model fit indices TLI = 0.958, CFI = 0.966, RMSEA = 0.059, SRMR = 0.158, and CHISQ = 130.711 (df = 97, p = 0.013). The path coefficient from the second-order penetration Pass skill factor to the first-order through pass skill factor was 0.942, the unbalancing DFL skill factor was 0.837, positioning skill factor was 0.724, and breaking DFL skill factor was 0.465, respectively.

The path coefficients from the through pass skill factor to each item were v4_Through pass (0.989), v3_Number of opposing players passed by one pass (0.832), v2_Forward pass distance (0.715), v1_A passer played with no press (0.508), v7_Square run (0.519), and v11_Receiving the ball forward direction (0.849). The path coefficients from breaking DFL skill factor to each item were as follows: v6_A receiver played with no press from opposing goal direction (0.576), v8_Diagonal run (0.872), and v15_DFL-MFL distance (0.556). The path coefficients from positioning skill factor to the items were v10_A receiver started running faster than a mark defender (0.958), v9_Running to behind the line (0.708), v12_Support player's positioning between opposing central defenders (0.374), and v5_Receivers' positioning outside of Wide Defender's view (0.817). The path coefficients from the unbalancing DFL skill factor for each item were v16_No coverage opposing player (0.938), v14_Imbalanced the opposing DFL (0.518), and v13_Numerical advantage (0.581). The pass coefficients were statistically significant ($P < 0.05$).

3.2. Item and test characteristics

The first eigenvalue obtained from an exploratory factor analysis of 16 items that satisfied construct validity was 5.97. This explained 37.33% of the total variance. There was a difference between the second eigenvalue (18.13%) and the lower levels. The factor loadings of all the items were positive. These results indicate unidimensionality in the 16 items.

Table 2 shows the characteristics of the 16-soccer penetration pass play items. The $\chi 2$ values for all items were not significant ($p \geq 0.05$). The mean ± standard deviation of item difficulty was 0.15 ±

Figure 2 Second-order CFA structure of penetration pass play items in soccer games

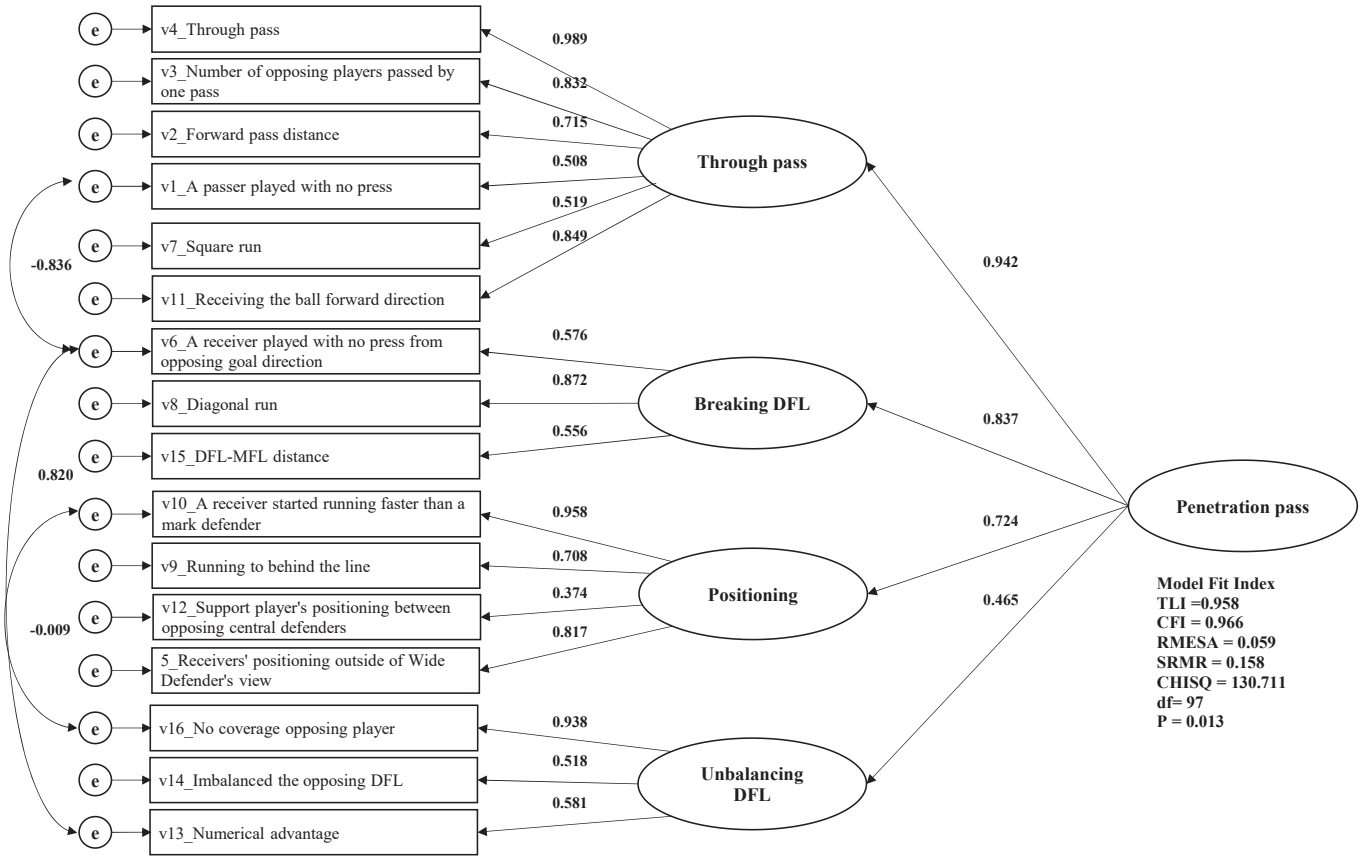


Table 2 Item characteristics of penetration pass play items in soccer games

Skill	ID	Item	Achievement rate (%)	Difficulty	Discrimination	Chi-value	df	p
Through pass	v1	A passer played with no press	94	-3.19	0.99	0.47	1	0.49
	v2	Forward pass distance	30	0.85	1.38	0.66	1	0.42
	v3	Number of opposing players passed by one pass	57	-0.21	1.93	2.79	1	0.09
	v4	Through-pass	61	-0.28	4.20	0.02	1	0.88
	v7	Square run	13	2.11	1.09	0.68	1	0.41
	v11	Receiving the ball forward direction	82	-1.14	2.43	0.70	1	0.40
Positioning	v5	Receivers' positioning outside of Wide Defender's view	38	0.50	1.43	1.99	1	0.16
	v9	Running to behind the line	25	1.31	1.02	0.49	1	0.48
	v10	A receiver started running faster than a mark defender	57	-0.22	1.78	3.27	1	0.07
	v12	Support player's positioning between opposing central defenders	48	0.21	0.40	0.19	1	0.67
Breaking DFL	v6	A receiver played with no press from opposing goal direction	58	-0.44	0.82	0.22	1	0.64
	v8	Diagonal run	32	0.66	1.90	0.77	1	0.38
	v15	DFL-MFL distance	31	1.05	0.90	0.71	1	0.40
Unbalancing DFL	v13	Numerical advantage	40	0.76	0.58	0.13	1	0.72
	v14	Imbalanced the opposing DFL	43	0.57	0.53	2.05	1	0.15
	v16	No coverage opposing player	53	-0.16	0.82	3.05	1	0.08
		M	48	0.15	1.39	1.14	1	0.40
		SD	21	1.19	0.94	1.11	0	0.24
		Max	94	2.11	4.20	3.27	1	0.88
		Min	13	-3.19	0.40	0.02	1	0.07
		Median	46	0.35	1.05	0.69	1	0.41

Notes: N = 100. ''Achievement rate' is calculated by number of achievement in each item divided by total number of samples. Difficulty' parameter represents the level of difficulty of the items. 'Discrimination' parameter represents how the items can differentiate the penetrative pass play with a high and low score.

1.19, and item discrimination was 1.39 ± 0.94. The invariance coefficient of item difficulty was $r = 0.85$ ($p < 0.05$), item discrimination was $r = 0.61$ ($p < 0.05$), and ability value was $r = 0.56$ ($p < 0.05$).

The reliability coefficient of the test for the criterion-referenced measurement test of the penetration pass play showed a maximum value of 0.90 at an ability value of -0.24, and the reliability coefficient of the test was more than 0.70 in the range from -1.6 to +1.6.

Figure 3 shows the correlations of the ability values with the test scores and the test characteristic curve for soccer penetration pass play. This shows the validity and goodness-of-fit of the test to the test characteristic curve. The criterion-related validity coefficient of the estimated ability values for the measured test scores was $r = 0.97$ ($p < 0.01$). The correlations between the ability values and the test scores were visually fitted to the test characteristic curve. The validity of the test for the result of the penetration pass was analyzed by comparing the mean ability values in the successful and unsuccessful groups. The result showed a significant main effect of the result of penetrative pass ($F(1, 98) = 22.28$, $p < 0.05$), and there were differences between the mean values of the success group (0.30±0.79) and the failure group (-0.45±0.73).

3.3. Criterion

Item difficulty in the IRT indicates the ability value when the achievement rate of the item characteristic curve is 0.5. **Table 3** shows a simple target criterion table for penetration pass play with 16 items.

4. Discussions

The purpose of this study was to develop a criterion-referenced measurement items of penetration pass play in the soccer games. In this study, a three-

Figure 3 Validity and goodness-of-fit of the criterion-referenced test of penetration pass play in soccer games

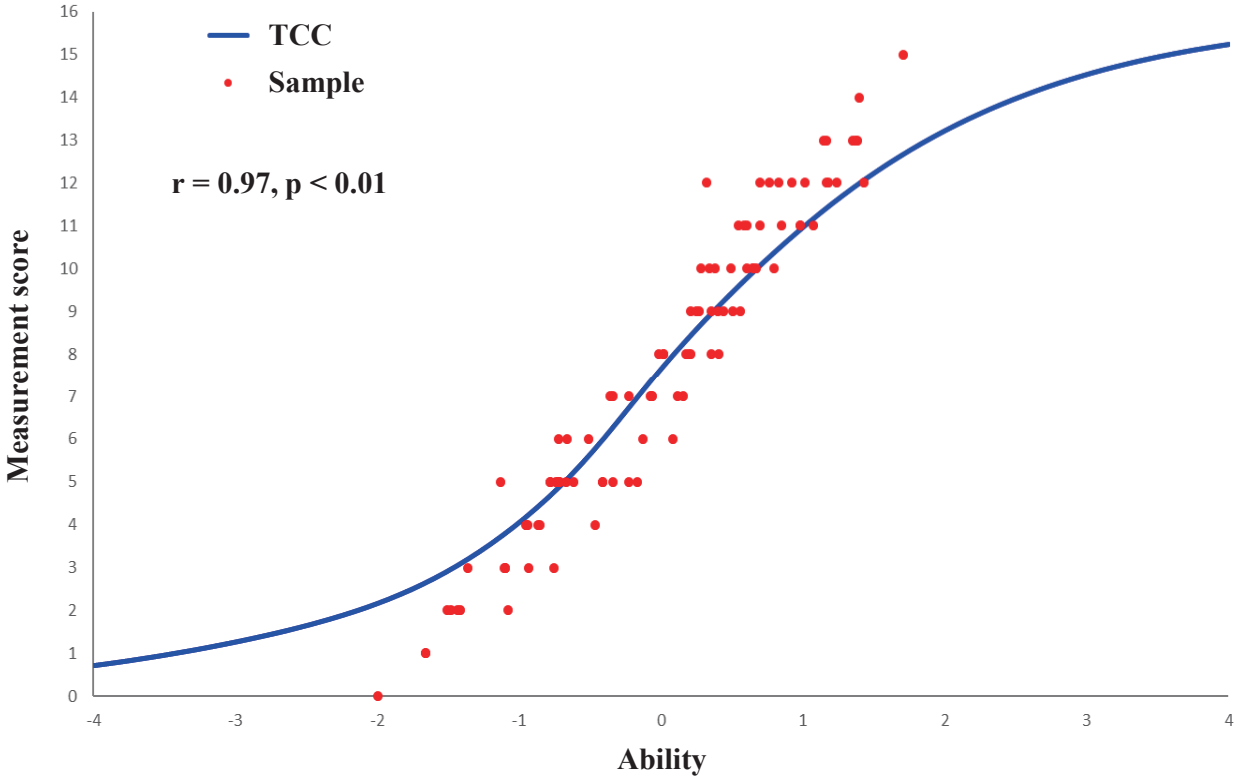


Table 3 Simplified criterion of penetration pass play in soccer games

Positioning	Through pass	Unbalancing DFL	Breaking DFL	T-score
	v7 Square run 66			
v9 Running to behind the line 60				60
			v15 DFL-MFL distance 58	
	v2 Forward pass distance 56			
		v13 Numerical advantage 55		
		v14 Imbalanced the opposing DFL 54	v8 Diagonal run 54	
v5 Receivers' positioning outside of Wide Defender's view 53				
v12 Support player's positioning between opposing central defenders 51				50
v10 A receiver started running faster than a mark defender 47	v3 Number of opposing players passed by one pass 47	v16 No coverage opposing player 47		
	v4 Through-pass 46			
			v6 A receiver played with no press from opposing goal direction 45	40
	v11 Receiving the ball forward direction 39			30
	v1 A passer played with no press 22			20

steps of scaling procedure was implemented. In the first step, this study constructed 16 measurement items that formed the basis for the qualitative causal structure of penetration pass play in soccer games. In the second step, exploratory and confirmatory factor analysis were used to demonstrate the skill structure of penetration pass play and to analyses validity of the 16 items. Finally, item response theory (IRT) with a two-parameter logistic model (2PLM) was used to construct 16 criterion-referenced measurement

items of penetration pass play in soccer games. The 16 criterion-referenced measurement items could be used for data-driven coaching of penetration pass play because those items are evidence of the causal structure and the criterion of penetration pass play success.

4.1. Construction of items of penetration pass skill

This study investigates the validated measurement items of penetrative pass skills through two steps of qualitative and factor analysis. The step of the factor analysis included three sub-steps; EFA, CFA and the second-order factor analysis.

First, this study showed that the structure of the penetration pass play differs between the qualitative and factor analyses. The reason for the difference between the cause-and-effect diagram (fishbone diagram) and the second-order CFA structure of soccer penetration pass play is considered to be the difference in the structure of the penetration pass as perceived by soccer experts and the structure of the penetration pass as represented by the data. In the cause-and-effect diagram, the structures are divided into the roles or the actions of the players in the penetration pass play, making it easier for coaches and players to understand penetration pass play from a coaching perspective. However, the skill structure examined in factor analysis is estimated based on the data structure, which is the correlation between measurement items. In the interpretation of skill structure by the second-order structure model, the structures of skill possibly reflect a more tactical domain than player roles and player actions. In other words, there may be a gap between tacit knowledge based on players' and coaches' experiences and the actual data structure, and this means analyzing skill structure from soccer match performance data should be an important learning experience in the tactical domain of soccer match performance for data-driven coaching.

This study found that penetration pass skill consisted of through pass skill, positioning skill, unbalancing DFL skill, and breaking DFL skill by the analysis of the second-order factor model of penetration pass skill. This study applied the second-order factor model because it was found the correlations between four factors after analysis of CFA model of the penetration pass skill. The through pass skill, which had the highest path coefficient (0.942), was considered an essential component of penetration pass play. Moreover, the all of the skills, through pass skill, positioning skill, unbalancing DFL skill, and breaking DFL skill contribute to the success of penetration pass plays.

Six-teen items of penetration pass play involved by four sub-skills, through pass skill, positioning skill, unbalancing DFL skill, and breaking DFL skill are validated measurement items of penetration pass skills by the second-order factor structure. Path coefficients from four sub-skills to sixteen observed items were generally high in range from 0.374 to 0.989. The item that shows the highest path coefficient is v4 Through pass (0.989). It is considered that a pass to break the opposing defense line and progress into the opponent half is the essential play of the penetration pass. Thus, v4 Through pass item is considered as highly validated item of penetrative pass skills. This means that v4 through pass could be used as a surrogate variable of penetration pass skill, which allows the analysis of causal relationship of penetrative pass in future research.

The second-order factor structure included items that measured players other than the passer and the receiver, and these results shows that not only relationship between a passer and a receiver of penetrative pass, but also creating tactical situation on the pitch is important to success the penetrative pass. For example, the items measuring the organization of the opponent defense line or positioning of supporting players on the pitch are included. As Tenga et al. (2010) shows the offence against opponent imbalanced defense leads to more goal scoring opportunity, it is considered that the skills to create imbalance and to break the opponent defensive block is key for successful penetrative passes. Moreover, to imbalance the opponent defense line, the positioning skill of players such as a passer, a receiver, and other players is essential. Positioning between the opponent central defender or start to run faster than the opponent marking defender makes difficult for the opponent team to maintain its defensive organization. Thus, the sub-skills in the second-order factor structure is essential skills for the penetrative pass, and the measurement items constructed in this study solves the common issues of studies that have not clarified the skill factors of penetrative pass plays in soccer games (Brooks et al., 2016; Taki and Hasegawa, 1998; Sekogawa and Omori, 2014; Wakita

and Murota, 2017).

4.2. Construction of criterion-referenced measurement items

After the analysis of item response theory, sixteen criterion measurement items were indicated as valid items. Parameter of the item characteristic are shown by item difficulty and item discrimination in the item response theory. The mean, maximum, and minimum item discrimination of the criterion-referenced measurement items of the soccer penetration pass play were 1.39, 4.20, and 0.40, respectively. It was confirmed that item discrimination met these criteria. The mean item difficulty value was 0.15, the maximum value was 2.11, and the minimum value was -3.19. To measure a wide range of differences in the ability values of subjects, the test should be composed of items with various difficulty levels (Toyoda, 2002). Item difficulty ranged from -3.19 to 2.11, indicating that the items were appropriate for measuring the differences in target play.

Item difficulty and item discrimination parameter allow for a deeper understanding of penetration pass play. For example, the v4 Through pass item, a subdomain of the through pass skill, has a relatively low item difficulty parameter (-0.21) and a high item identification parameter (4.20) in **Table 2**. This item shows a high factor loading (0.99) in the second-order factor model in **Figure 2**, meaning that parameter is related to the v4 Through pass item and the common factor (subskill; through pass skill). The item difficulty parameter shows the difficulty of successfully completing the criterion, and the item discrimination parameter shows how the item can differentiate the penetration pass skill with a high or low score (θ). The lower the difficulty of the v4 Through pass item means that the item is essential to a successful penetration play, and the high discrimination parameter means that the items has a power to differentiate through pass skill level around the ability score -0.21. In same skill domain (through pass skill), v7 Square run item shows the high item difficulty (2.11) and high discrimination (1.09). This means that v7 Square runs are difficult to achieve, and if the v7 Square run is achieved, the penetration pass play is considered to be highly skilled play. Thus, although the second-order factor model only examines skill structures such as v4 Through pass and subskill domain through pass skills, the difficulty of the item can be interpreted by applying item response theory.

IRT analyzes the amount of information in the item information function and test information function to check the accuracy of the constructed test. The test information content and test reliability coefficients, which indicate the accuracy of all 16 test items, were analyzed. If the test reliability coefficient was >0.70, the test was considered acceptable (Nunnally, 1978; Aoyagi, 2005). The maximum test information amount for all 16 items was 8.71, with an ability value of -0.24. The maximum reliability coefficient of the test was 0.90 at the ability value -0.24. The reliability coefficient of the test was >0.7 between ability values of -1.60 and 1.16.

There was a significant correlation between the measured and estimated ability values ($r = 0.97$, $p < 0.05$). Criterion-related validity of the test was confirmed. The scatter plot of the penetration pass play ability values showed a good visual fit to the test characteristic curve. There was a significant difference between the mean values of the successful and unsuccessful penetration pass play groups ($F(1, 98) = 22.28$, $p < 0.05$), confirming the validity of the test. These results confirmed the reliability, validity, and goodness-of-fit of the model of the criterion-referenced measurement test for penetration pass play, which consisted of 16 items.

By arranging the items of penetration pass plays in order of item difficulty, a simplified criterion table of soccer penetration pass play for penetration pass plays was constructed (**Table 3**). Using this table, it was possible to estimate the ability values involved in penetration pass plays and evaluate the target skill in accordance with the achievement criteria. For example, the items of high difficulty levels are: v9 Running behind the line in the subskill: Positioning, v7 Forward passing distance over 40m in the subskill: Through pass, v13 Numerical advantage in the subskill: Unbalancing DFL, v15 DFL-MFL distance shorter than 6.7m in the subskill: Breaking DFL. If your team or players achieve these items during a penetration pass play, then the penetration pass play is considered to be at a very high skill level. On the other hand, v1 A passer played with no press, or v4 Through pass are relatively easy to achieve. In other words, these items are essential to achieve for a high level of penetration pass play. It is thought to be useful for the coaching method, which makes the player master the penetrative pass skill step-by-step.

In this study, 16 criterion-referenced measures of penetration pass play are presented, which not only serve as the basis for penetration pass skill, but also as the basis for the criteria for penetration pass play. Therefore, these items could be used as evidence of data-driven coaching for penetration pass play in soccer.

5. Conclusions

The purpose of this study was to develop criterion-referenced measurement items of penetration pass play in soccer games. For this purpose, the qualitative causal structure, measurement items, and achievement criteria of penetration pass play in soccer games were constructed by applying cause-and-effect analysis with the Delphi method. The second-order factor structure model of penetration pass play was examined by applying structural equation modeling, and the criterion-referenced measurement items of penetration pass play items were constructed by applying IRT. The following conclusions were drawn:
1) The criterion-referenced measurement items of penetration pass play in soccer games consisted of through pass skill (six items), positioning skill (four items), unbalancing DFL skill (three items) and breaking DFL skill (three items) and the items have construct validity.
2) The criterion-referenced measurement items of the penetration pass play in soccer games are unidimensional, goodness-of-fit to a 2PLM, and have invariance of estimated item difficulty, item discrimination, and ability values.
3) The criterion-referenced measurement test of penetration pass play in soccer games has test reliability, validity, and goodness-of-fit to the 2PLM.

Conflict of Interest

The authors declare that they have no conflict of interest in the authorship and publication of this contribution.

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