Material

Analytic study on the position and height of rebound balls in basketball

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The purpose of this study was to consider the relation between failed shots and rebound balls in basketball. The object of study was the 1st game of the 200X-X+1 W-League Playoff Finals. In this study, the position coordinates of all players and the ball were calculated by 3-Dimensional photography analysis in which the DLT method was used. The main results were as follows:1) A significant positive correlation was shown between shot distance and rebound ball distance. That is, the distance of the rebound ball increased in proportion to the shot distance; 2) In the 3 point shot, shots from the left side fell on the right side, opposite the shooter, in many cases. On the other hand, shots from the right side fell on both sides. Furthermore, shots from the middle fell on the middle side, which is the same side as the shooter;. 3) A negative correlation tendency was shown in the relation between the distance from the goal and the height at the time possession of the rebound ball was gained; 4) The average and standard deviation of the height of rebound ball acquisition of 2-point shots was 2.07±.056m, and 3-point shots was 1.99±0.39m. Moreover, the highest positions at which possession of the ball was gained were 2.75m and 2.49m.

Key words : game performance analysis, 3-dimensional photography analysis, rebound position, vertical height

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1. Introduction

Basketball is a ball game in which two teams try to score points against one another within a fixed amount of time and within the boundaries a comparatively small court measuring 28m long by 15m wide. Unlike many other ball games, basketball is characterized by the performance of continuous and speedy offensive and defensive play aimed at scoring or preventing the scoring of points. Two teams of 5 players compete through their interactions with one another on the court. Due to the characteristics of the game, it is difficult for basketball players to analyze the complex interrelationships during the course of a game and improve their performance. In motor learning, however, monitoring of performances and the use of feedback have a great effect on subsequent learning activities and the improvement of skills. In other words, it is necessary for the improvement of performance to conduct an objective analysis/evaluation of various events occurring during the course of a game.

A large number of analytic studies on basketball game performance has been carried out because the significance and necessity thereof has been increasingly recognized by coaches (Okuda et al., 2005). In such studies, a variety of events occurring in games have been quantified for use in training, skill practice, as feedback for strategic plans, and for the improvement of performance of individual players or teams in the course of coaching or team management (Ohashi, 1999). While providing a large quantity of detailed numerical data, however, current game performance analyses fail to produce adequate results in terms of providing feedback to players (Okuda et al., 2005; Uchiyama, 2004). According to Ohashi (1999), "Since motions during a game have a significant effect on game performance, the analysis of motions in actual games is effective in upgrading game skills and providing helpful suggestions for training methods suitable for the characteristics of the game." This means that not only

individual or quantitative game performance analysis but also the comprehensive study of diversified performances occurring in actual games are needed in combination with numerical data, including points scored or prevented, number of shots, and success rates.

In basketball, according to Yoshii (1994), the two participating teams compete for "possession of the ball" and "scoring" with the object of "scoring as many points as possible" while "preventing the opponent team from scoring." Therefore, an increase in the number of offensive motions made by one team and a decrease in the number of offensive motions made by the opposing team are extremely important factors in the outcome of the game. Based on the results of past studies, gaining possession of the ball on rebound has been shown to have a direct effect on this (Oga et al., 2007; Sasaki, 1980; Takagi, 1985). Gaining possession of the ball on rebound by the offensive team leads to an increase in the number of offensive motions and shots, while gaining possession of the ball on rebound by the defensive team leads to an offensive opportunity such as fast offense and a denial of offensive opportunity to the opposing team (Watanabe & Kobayashi, 2002).

Numerous studies have been conducted on gaining possession of the ball on rebound, which has an important impact on the outcome of the game (Oga et al., 2006; Sasaki, 1980; Shibata et al., 2002; Tagagi, 1986; Uchiyama, 1987). Such studies can be generally classified into 3 categories; that is, studies on the relationship between rebound skills and game results with a focus on the skills of individual players, including constitutional factors such as body height (Oga et al., 2006, 2007); studies on the relationship between rebound methods/rates and scoring (Goto & Iwaki, 2006; Sasaki, 1980); and studies on the relationship between missed shots and the landing position of a rebounded ball (Goto & Iwaki, 2006; Shibata et al., 2002; Uchiyama, 1987). Of these, studies on the landing position of a rebounded ball are largest in number. Yoshii (1994) has pointed out the need to study methods of predicting the landing position of rebounds, claiming that players who can anticipate where a rebounded ball will land based on their knowledge in this field are able to move to an advantageous position faster than opponent players and to gain possession of the ball.

Shibata et al. (2002) experimentally investigated landing the position of rebounds in 3-point (hereinafter referred to as 3P) shots. As a result, it was reported that a ball rebounded in a 3P shot never lands outside the 3P line or behind the backboard. It was also reported that a rebounded ball in a shot made from the corner or at an angle of 45 degrees often lands on the shooter's side of the court as often as on the opposite side, results that contradict those reported by Takagi (1986), Uchiyama (1987), and Goto & Iwaki (2006), who claimed that rebounds in many of such shots land on the opposite side of the court from where the shooters were. Uchiyama (1987) has shown that a ball often lands within 2.15m from the goal in a 3P shot made from the top of the key. Takagi (1986) has demonstrated that the greater the distance of a missed shot from the goal, the farther from the goal that the rebounded ball lands, and that the ball in a failed 3P shot often falls on the point approximately 4m away from the goal. While helpful to players for improving skill in anticipating where a ball is more likely to land, however, these studies contain some problems such as a limitation in analysis caused by limiting the landing position of rebounds to the inside of the court and a lack of consideration of the influence of defensive motion against shooting.

Meanwhile, in his investigation of the relation between shooting position and rebound position during a game, Takagi (1985) has demonstrated that a ball in a failed shot made from the corner or at an angle of 45 degrees often lands on the opposite side from the shooter and that a ball in a shot made from the top of the key lands in front of or at an angle of 45 degrees to the right or left of the shooter at a rate of 88%. Watanabe & Kobayashi (2002) have shown that rebounding is often performed in and around the painted area and that, therefore, it is important to take up a rebounding position in this area. In the investigation of actual games in these studies, the target of analysis is a 2-dimentional position or area of rebounds with no consideration of height. As is clear from the fact that the goal is fixed in space at the height of 3.05m, basketball requires a 3-dimentional analysis which includes height. In order to analyze gaining possession of a rebounded ball in the air, it is necessary to examine not only 2-dimensional location but also height.

In recent years, a new type of game performance analysis has been conducted to directly measure the distance of movement of the ball or players during a game (Oba & Okuda, 2007; Okuda et al., 2007). In such analytical studies, accurate positions of the ball and players are

directly measured as longitudinal 3-dimentional position coordinate data. Based on this data, researchers calculate data for physical strength factors, such as movement distance and speed of the ball and players during a game, as well as data for strategic factors, such as the inter-relationship among players and space quantification employing power balance models. Overcoming the existing limits of analysis, this new method has enabled the stereoscopic measurement and evaluation of the movements of the ball and players during a game.

In this study, movements of the ball during an official basketball game were measured employing a 3-dimentional photography analysis (DLT method) in order to clarify the relationship between failed shots and rebounds in consideration of height when gaining possession of rebounds, which have as yet not been elucidated.

2. Methods

2.1. Sample

The target of analysis in this study was the 1st game of the playoff finals (Team A vs. Team B) of the 200X Women's Japan Basketball League (WJBL) Championships. This game ended in a 98-73 win for Team A (21-21, 21-13, 20-18, 36-21). The length of the game, excluding halftime, intervals, and charged timeouts, was 32.1 minutes for the first half (1st period: 15.7 min., 2nd period: 16.4 min.) and 33.5 minutes for the second half (3rd period: 14.7min., 4th period: 18.8min.). The analysis covered the entire game. Videotaping was conducted with the consent of the Osaka Basketball Association.

2.2. Data Collection

The position of the ball and players during the game was recorded employing the DLT method in which 2-dimentional images videotaped by multiple cameras were converted into 3-dimentional coordinates. Videotaping of the full game was conducted at 30 Hz employing an LED synchronizer (PTS-110; DKH Co. Ltd., Tokyo, Japan) and 4 cameras, enabling coverage of the entire court. In videotaping, no lenses that distort images (e.g., wide conversion lens) were used. The 4 cameras were set in such a way that each covered the same reference points (e.g., goal, and points at the intersections of the sidelines with the baselines).

The images recorded by the 4 cameras were digitized every 1/4 second by video capture board and were uploaded onto a computer. From this, coordinate data (X, Y, Z) of the ball and 10 players on the court was produced using Frame-DIAS II 3-dimentional analysis software (MP Japan Co. Ltd., Tokyo, Japan). Using a method similar to that employed by Oba & Okuda (2007) and Okuda et al. (2007), the position of the players was digitized at waist height based on the subjective judgment of the investigators. Regarding the 3-dimentional coordinates, the X-axis was set as parallel to the sideline, the Y-axis as parallel to the baseline, and the Z-axis as vertical direction. For digital calibration, a calibration pole ($\geq$ 5m) was set up on each of the 4 points at the intersections of the sidelines with the baselines and was used as a coordinate point. The measuring errors produced by the DLT method in the directions of the X-axis, Y-axis, and the Z-axis were 0.03 m, 0,01 m, and 0.04 m, respectively.

2.3. Data analysis

Movement distance and speed of the ball and players on the court were calculated using the 3-dimentional position coordinate data gained by the above-mentioned analysis method. Though some players were replaced during the game, newly-inserted players took up the same positions as those of the replaced players without any significant change in strategic action, including offense formation and defense system. Therefore, the replaced and inserted players were regarded as the same when conducting analyses in this study. Successful shots and shots made below the hoop (shots made within 1m from the goal) were excluded from the data to be analyzed. The 3P shots made from the half line immediately before the end of a period (1 each for the teams A and B) were also excluded from the data for analysis. Position of shooting was defined as the position of a shooter at the moment of ball release, while position of gaining possession of a rebound ball was defined as the position of a rebounder at the moment when her hands touched the rebounded ball or the position that a loose ball when in landed on the court without being touched by a player. For the purpose of distinguishing the landing area of the rebounded ball, the area located to the left of the line connecting the goal and the intersection of the left side line and the half line was defined as the left

side; the area located to the right of the line connecting the goal and the intersection of the right side line and the half line was defined as the right side; and the area located in between these 2 areas was defined as the top side. Table 1 shows the box scores of the team and the players which were used for analysis.

Table 1. Game score for each team and all players

	3P shot		2P shot		FT shot		rebound	
	made	attempt	made	attempt	made	attempt	offense	defense
A-team								
PG	1	2	4	7	7	8	1	7
SG	5	13	5	6	0	0	2	2
F	3	8	2	3	2	2	2	7
PF	0	0	9	17	2	4	3	2
C	0	0	4	10	12	14	2	3
Total	9	23	24	43	23	28	10	21
B-team								
PG	2	7	0	3	0	0	1	6
SG	0	5	5	9	1	1	3	1
F	1	3	7	9	4	6	3	0
PF	0	4	9	16	0	0	3	6
C	0	0	8	12	1	1	1	4
Total	3	19	29	49	6	8	11	17

Pearson's product-moment correlation coefficient was used for statistical processing of the relation between shot distance and distance from the goal when gaining possession of rebounds and the relation between height and distance from the goal when gaining possession of rebounds. The significance level was set at less than 5%. The statistical levels which were 5% or higher but less than 10% were classified as demonstrating a significance tendency.

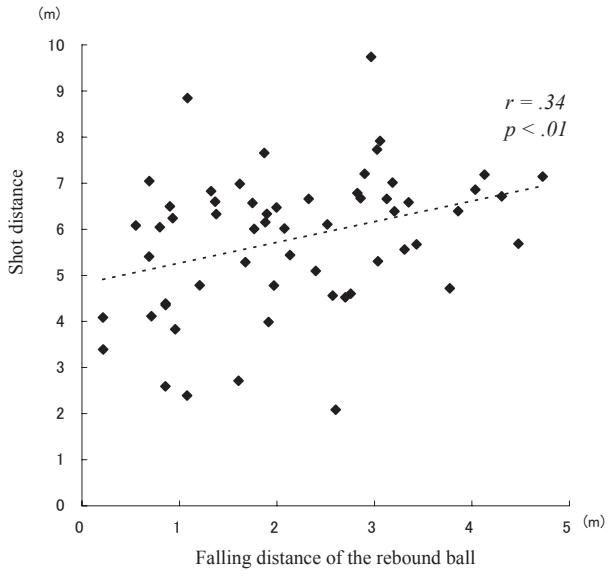

Figure 1. The relationship between the shot distance and he falling distance of the rebound ball

3. Results and Discussion

3.1. The relationship between the shot position and the falling position of the rebound ball

3.1.1. Shot distance and falling distance of the rebound ball

Figure 1 shows all shot and landing distances of rebounds.

Shots and rebound distances examined using Pearson's product-moment correlation coefficients calculated revealed a comparatively weak significant relation ($r=.34$, $p< .01$). This supported the results reported in past studies. Similar to the results reported by Takagi (1985, 1986), it was suggested that the longer the shot distance was, the longer the landing distance of a rebounded ball was.

3.1.2. A case of 3P shot

Figure 2 shows planimetric rebound position by shot area.

There were ten 3P shots in total made from the left side used for analysis. Of these, 6 shots (60%) were rebounded on the right side, the side opposite the shooters; 3 shots (30%) were on the top side; and only 1 shot (10%) was on the left side, where the shooter was. There were seven 3P shots in total made from the right side, of which 3 shots (approx. 43%) each were rebounded on the right side and the left side, while 1 shot (approx. 14%) was on the top side. Although only 1 game was analyzed in this study, the results regarding the 3P shots made from the left side supported the results reported by Takagi (1985), who investigated shots made during a game as opposed to Shibata et al. (2002), who investigated shots in an experimental environment. Shots made from the angle of 45 degrees landed on the top side. Shots made closer to the corner, however, seldom landed on the top side. Rebounded balls were often gained at a distance of approximately 1-1.5m from the goal when observed at the point below the goal, and were gained near the line of the painted area; that is, at a distance of approximately 4m from the goal, when observed near the top side.

There were 11 shots in total made from the top side. Of these, 7 shots (approx. 64%) were rebounded on the top side; 2 shots (approx. 18%) were on the left side; 1 shot (approx. 9%) was on the right side; and 1 shot rebounded against the hoop and fell behind the backboard. Similar

to the results reported in past studies, rebounds tended to land on the side where shooters were at a rate that was higher than corresponding rates reported in the studies of Takagi (1986) and Shibata et al. (2002), which were 32% and 52%, respectively. The rebounds were gained within the range of 0.7-4.7 m (mean 2.4±1.3 m) from the goal. Shibata et al (2002) demonstrated that the ball in 3P shots made from the top side landed in the top area (within 2.15 m from the goal) at a rate of approximately 43% and that they rarely landed around the free throw line. Watanabe & Kobayashi (2002) reported that rebounds were gained during games in an area that was within approximately 3.5m from the goal at a rate of approximately 90%. In this study, as in the past studies, rebounds were gained in an area located between the goal and the free throw line at a rate of approximately 90%. However, there were some cases in which balls were gained in an area located outside of the free throw line, though small in number.

3.1.3. A case of 2P shot

Figure 3 shows planimetric rebounding positions by shot area.

There were twelve 2 point (hereinafter referred to as 2P) shots in total made from the left side, which were used for analysis. Of these, 5 shots (approx. 42%) were rebounded on the left side, where the shooters were; 4 shots (approx. 33%) were on the opposite side; and 3 shots (25%) were on the top side. There were eleven 2P shots in total made from the right side, of which 5 shots (approx. 45%) were rebounded on the left side, the side opposite the shooters; and 3 shots each (approx. 27%) were on the top and right sides. While the ball in the shots made from the right/left

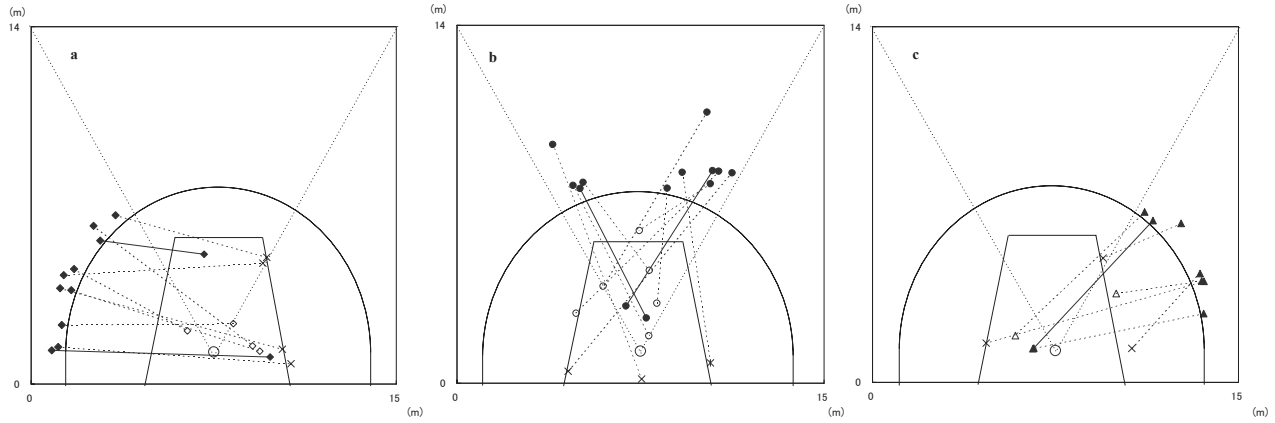

Figure 2. The rebounding position for every 3P shot area

Note."a" shows the shot from the left side." b" shows the shot from the top side. "c" shows the shot from the right side.
× shows the rebound ball which fell on the floor, without touching players.
Painting out sign and solid line show offensive rebound.

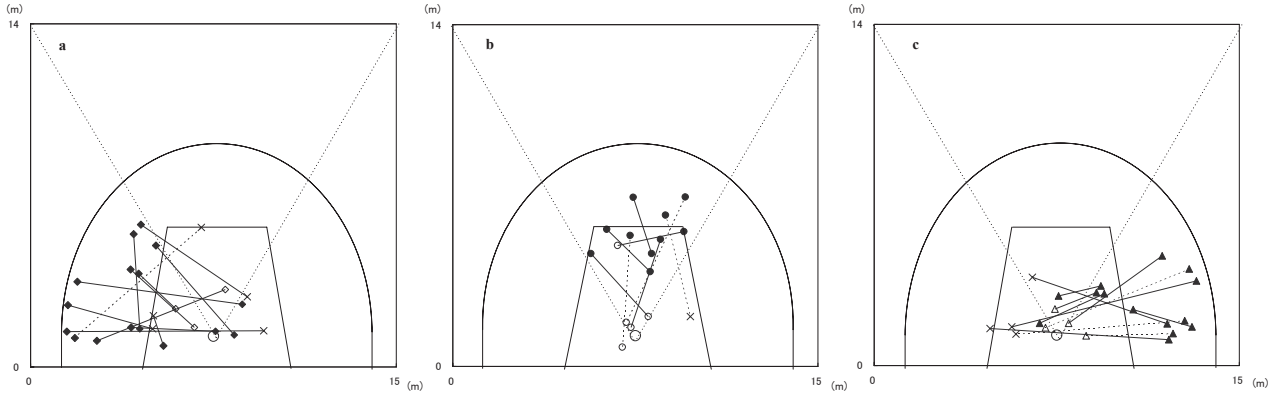

Figure 3. The rebounding position for every 2P shot area

Note."a" shows the shot from the left side." b" shows the shot from the top side. "c" shows the shot from the right side.
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Painting out sign and solid line show offensive rebound.

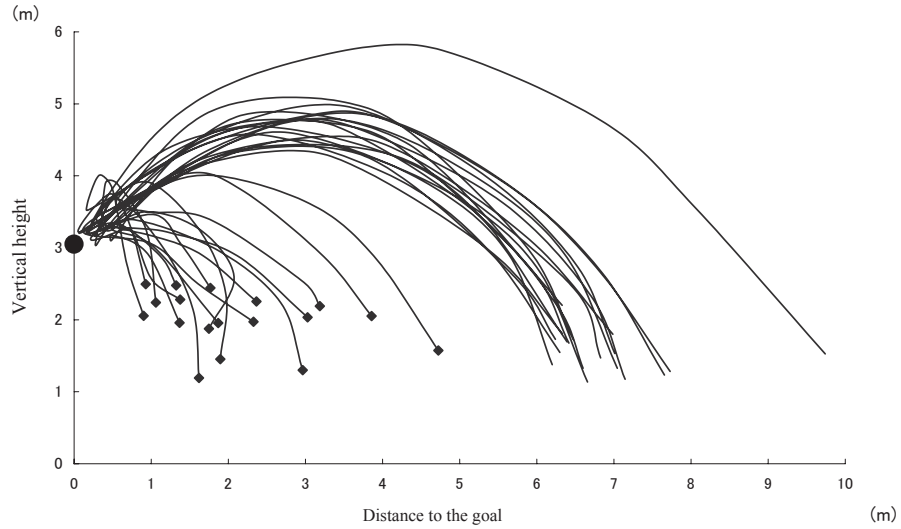

Figure 4. The vertical track of the 3P shot and the rebound ball
Note. ◆ shows the position of the rebound ball when possession was gained.
● shows the basketball goal.

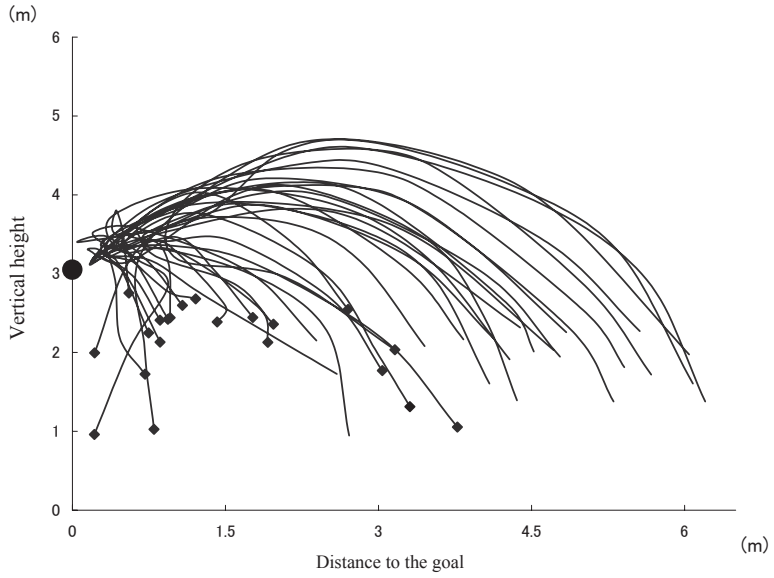

Figure 5. The vertical track of the 2P shot and the rebound ball
Note. ◆ shows the position of the rebound ball when possession was gained.
● shows the basketball goal.

sides landed on the top side at the rate of approximately 10-15% in the study by Takagi (1985), they landed on the top side at the rate of approximately 25% in this study. The results of this study were similar to those of Goto & Iwaki (2006), in which rebounding positions for 2P shots during a men's game were investigated.

There were eight 2P shots in total made from the top side, of which 6 shots (75%) were rebounded on the top side and 1 shot each (approx. 13%) was on the right and left sides. Compared to the corresponding rates in the studies reported by Takagi (1985) and Goto & Iwaki (2006), which were approximately 23% and 50%, respectively, the rate of landing on the top side was high in this study.

Because only one game was analyzed in this study, however, the number of shots analyzed was too small to produce statistical reliability. Further research is required.

3.2. Analysis about the height of the rebound ball

In order to examine the height at which players gained possession of rebounds, 18 of the 3P shots and 21 of the 2P shots were analyzed, excluding the shots that landed directly on the floor without being touched by players (3P: 10 shots; 2P: 10 shots). Figure 4 shows the trajectory of 3P shots and rebounds, and Figure 5 shows those for the 2P shots and their rebounds.

Heights and distances from the goal of rebounded balls examined by Pearson's product-moment correlation coefficients revealed a comparatively weak negative correlation ($r=.34$, $p< .01$), though as significance tendency (See Figure 6). This indicates that the closer the rebounded ball was to the goal, the higher the position of possession was; and that the greater the distance of ball landing, the lower the height of rebound position. Therefore, the closer the rebounded ball lands to the goal, the more necessary it is for players to occupy the anticipated space in advance to take up an advantageous position for box out or to prepare to move and rebound instead of standing and waiting for rebound chances.

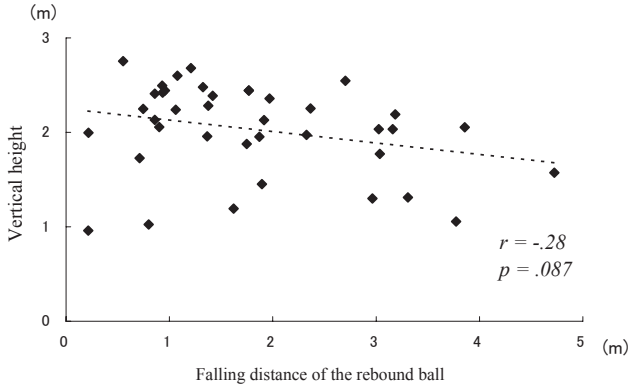

Figure 6. The relationship between falling distance and vertical height of the rebound ball

When gaining possession of rebounds from 2P shots, the highest position was 2.75m with a mean and standard deviation of 2.07±0.56m. The corresponding values in 3P shots were 2.49m as the highest position and 1.99±0.39m as the mean and standard deviation. Though there was a difference of 26cm between 2P and 3P shots for the the highest position at which possession of a rebounded ball was gained, there was only a minor difference (by approx. 8cm) between the two in terms of mean heights.

Based on their investigation of actual games, Takei et al. (1984) reported that a rebounded ball landed within 3.5m of the goal and that, therefore, it was necessary for players to occupy this area. Some studies on 3P shots have reported that rebounded balls landed within 2.15m of the goal (Shibata et al, 2002) or 4.20m from the goal (Uchiyama, 1987).

Considering that these distances were calculated with arbitrary area zones set on the court, however, they were subject to analytical restrictions in terms of accuracy. In addition, because they indicated where rebounded balls landed, they are thought to be insufficient for providing instruction methods for improvement of game performance to catch rebounded balls. Heights at which rebounds of 2P shots were gained in consideration of distance from the goal were 2.01±0.60m at a distance of 0-1m (10 of 21 shots) , 2.43±0.19m at a distance of 1-2m (6 of 21 shots), and 1.74±0.59m at a distance of 2-3.7m (5 of 21 shots). Similarly, in 3P shots they were 2.04±0.42m at a distance of 0-2m (11 of 18 shots), 1.84±0.49m at a distance of 0-2m, (3 of 18 shots), and 1.96±0.27m at a distance of 3-4.7m (4 of 18 shots). For rebounded balls from 2P shots were gained at a height that was larger than the mean height, 2.07m, the distance from the goal was 1.39±0.62m. Similarly in 3P shots, the distance from the goal was 1.98±1.06m. These results showed that players gained possession of rebounds often by jumping to them at an approximate distance of 1.4m from the goal for 2P shots and 2m from the goal for 3P shots. Considering that this area is crowded with players during a game, it is supposed to be necessary for players to take aggressive action (e.g., box out) to occupy the advantageous zone or to jump into a running rebound if the zone is unoccupied in order to take possession of the ball within 1.4m from the goal in 2P shots and 2.0m from the goal in 3P shots.

4. Conclusion

This study was conducted in order to clarify relations between missed shots and rebounds with consideration of ball landing positions including heights by measuring ball movements in an actual basketball game through a 3-dimentional photography analysis based on the DLT method. As a result, game performance in terms of the height at which rebounds were gained was revealed for the first time.

Since it was only one game of WJBL playoff finals was analyzed, however, the number of shots used for analysis in this study was smaller than that used in past studies, making figures for the rate of landing positions of rebounds in the top side being no more than an estimation. The number of samples for analysis should be increased in future studies. What was analyzed in this study was a women's game only. Different results might be obtained in an examination of male players making only one-hand shots. It is believed that further and more detailed studies will provide more helpful and interesting information to instructors.

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