Original paper

Advantages Taller Players Have When Attempting Field Goals in Basketball Games

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Ⅰ. INTRODUCTION

Height has been consistently used as one of the indices for identifying talent in young players (Abbott et al., 2005). The success of shooting the ball into the hoop without touching the rim or the backboard is determined by the entry angle (i.e., the angle at which the ball approaches the hoop), which is influenced by the height, speed, and angle at which a player releases the ball (Brancazio, 1981; Hay, 1985; Miller and Bartlett, 1993). The air resistance encountered by the ball in flight is small (Brancazio, 1981) and therefore negligible (Hay, 1985). To increase the probability of a shot's success, shooters are required to project the ball in a manner that will place it on the optimum trajectory. If the ball approaches the target basket vertically (i.e., the entry angle is 90 degrees to the horizontal plane), the margin between the ball and the "apparent" hoop reaches a maximum (Hay, 1985). The apparent shape of the hoop from where the ball approaches the target basket becomes increasingly ellipsoidal as the entry angle decreases, and this shallower approach decreases the margin between the ball and the apparent hoop (Hay, 1985). The ball cannot pass through the hoop when it approaches from below the entry angle (less than 32 degrees, see Brancazio, 1981), as the diameter of the ball would be greater than the apparent diameter of the hoop.

Brancazio (1981) focused on the optimum trajectory for increasing the probability of a shot's success. He sought to obtain the optimum release angle by ascertaining the margin for error for a particular angle of projection and a shot at minimum release speed. He shows that the optimum release angle is found by adding 45 degrees to one-half of the angle of incline to the hoop. Knudson (1993) reported that "shooting at the minimum speed has several advantages: increased accuracy, limiting fatigue, and maximizing the possibility that the ball will pass through the basket." Several other researchers have investigated the size of the optimum release angle (Mortimer, 1951; Hamilton and Reinschmidt, 1997). Their results found that the optimum release angles were within the range of 49.2 degrees to 59.75 degrees at the free throw (FT) position. The differences in the optimum release angle may be attributed to different release heights (Hamilton and Reinschmidt, 1997).

The release height relates to an optimum release angle, such as the minimum-speed release angle (Brancazio, 1981). The minimum-speed release angle, release speed, and projectile force become smaller as the release height increases; thus, the margins for error in angle and speed then become larger (Brancazio, 1981). In addition, as the release angle increases, the same one degree of error in the release angle causes the ball to deviate farther from the center of the rim (Mortimer, 1951). Taken together, a smaller release angle at a higher release point has a greater margin for error. Taking into account the margin for error a shooter has in launching his/her shot, Maugh (1981) calculated the width of the scoring band. The "scoring band" refers to the width of the shooter's margin for error in the path a ball takes (i.e., the ball's trajectory) while in flight to go through the hoop (Maugh, 1981). The calculations concluded that the width of the scoring band increases by 18% at a release height of 2.74m when compared to a height of 2.13m. Thus, taller players have a theoretical shooting advantage in basketball.

In actual games, the jump shot is considered to be the most important shooting action (Hess, 1980). The

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height of the release ratio, which is the release height divided by the player's height, is higher for elite shooters than poor shooters (Hudson, 1985). Moreover, the height of the jump at release decreases as shooting distance increases (Miller and Bartlett, 1993; Okazaki and Rodacki, 2012), and then, the increased probability of a goal owing to a greater release height may be overridden by the body's upward movement to help provide force to the ball (Miller and Bartlett, 1993). In addition, Miller and Bartlett (1996) reported that the release height of taller players (centers) from a long shooting distance is less than that of shorter players (guards and forwards). This finding suggests that taller players may not always score more easily than shorter players in actual games. In particular, the advantage of a player's height may decrease when shooting from a greater distance, such as when aiming for a three-point field goal (3FG).

This study attempts to answer the following question: In actual games, is it easier for taller players to score than shorter players? The following two lower-level objectives were set:

(1) To clarify the influence that the shot area has on the relationship between height and shot success rate (SSR) in actual games.

(2) To clarify the influence of the horizontal distance from a basket on the relationship between height and SSR in cases where there is no disturbance from opponents.

Ⅱ. METHODS

1. Relationship between player's height and SSR in actual games

The first phase of the study examined the scoring advantage taller players have for each of the 2FG, 3FG, and FT shot areas by analyzing the correlation coefficients between the players' heights and SSR based on actual game data. Data on players' heights were collected from the Kanto Collegiate Basketball League Program (2013), and shot performance data were extracted from the official records (KCBBF, 2013) of the Kanto Collegiate Basketball League Division 1-2 (2013). A total of 180 games were held in the league, which consisted of 20 teams. The SSR season mean for each of the three shot areas (2FG, 3FG, and FT) for each of the 317 male players (height: $M = 1.85$m, $SD = 0.08$m, $Max = 2.06$m, $Min = 1.65$m) was calculated by dividing the number of shots made by the number of goal attempts. The statistical analysis was performed using the distributed software SPSS, ver. 20.0 (IBM Japan, Ltd., Tokyo, Japan).

Next, correlation (Pearson's correlation coefficient) and regression analyses between the players' height and SSR for each of the three shot areas were conducted (Figure 2). In addition, the difference in SSR for both 2FG and 3FG compared with SSR for FT was computed for each player. Regarding 2FG and 3FG, correlation and regression analyses were conducted between player height and decreases in SSR (Figure 3). These analyses helped determine the effect of player height on SSR while factoring out the difference between players in relation to ball-control ability.

The advantage of a higher release point derived from the physical characteristics of a taller player may be lost as the shooting distance increased, since longer shots demand greater accuracy (Elliott, 1992). Further analysis was conducted to examine the effects of player height and FT SSR (as an index of the accuracy of throws) on SSR for both 2FG and 3FG using forced-entry multiple regression.

2. Analyses of performances in shooting trials

In the second phase, data from shooting trials involving 36 male basketball players were used to analyze the relationship between the players' heights and SSR. This test was performed to examine this relationship without the possible intrusive effects caused by the presence of opposing players.

Thirty-six male collegiate basketball players (2013 Kanto Collegiate Basketball League Division 3; age: $M = 19.8$ years, $SD = 1.93$ years; height: $M = 1.77$m, $SD = 0.07$m; athletic experience: $M = 10.6$ years; $SD = 1.83$ years) participated in a total of 500 shooting trials each. All were active players on a collegiate basketball team.

In this set of trials, the participants were asked to stand in front of the backboard and attempt to make a goal using a one-handed shot with their feet flat on the floor (not a jump shot). The optimal trajectory of the shots has been studied for the swish shot, where the ball touches neither the rim nor backboard (Mortimer, 1951; Brancazio, 1981; Maugh, 1981; Hamilton and Reinschmidt, 1997; Okazaki and Rodacki, 2012). With reference to a previous study (Miller and Bartlett, 1993), shots that directly passed through the hoop without touching the rim and/or backboard were counted as successful shots. Five shooting distances (1.0, 2.5, 4.0, 5.5, and 7.0m) from just under the center of the hoop were set. The setting of the distance is assumed as follows: 1.0m is the neighborhood of a no-charge semi-circle, 2.5m is the central neighborhood in the restricted area, 4.0m is the neighborhood of the free-throw line, 5.5m is the free-throw line rear, and 7.0m is three-point line rear. All participants began shooting from the 1.0m position. After every 25 shots, the shooting distance was increased in 1.5m increments until it reached the 7.0m position. After 25 shots at the 7.0m position, the shooting distance was then decreased in 1.5m increments to the 1.0m position, again with 25 shots for each position. These increases and decreases in shooting distance were repeated a total of two times. Thus, each participant attempted 100 shots from each position, making a total of 500 shots. Throughout the trials, the players were allowed to rest after every 25 shots.

The same statistical package was used for data processing as in the first phase. Repeated measures of one-way ANOVA with Greenhouse-Geisser correction were performed to test the effect of shooting distance on SSR. Subsequently, the Bonferroni post-hoc test was used if the ANOVA showed that shooting distance had a significant effect on SSR. Next, a correlation analysis (Pearson's correlation coefficient) between player height and SSR was conducted for each shooting distance.

The study, including consent procedure, was approved by the Ethics Committee of Juntendo University (approval number 26-27). The players who participated in the shooting trials were age 18 or older and gave their informed written consent.

Ⅲ. RESULTS

1. Influence of player height on SSR in actual games

For each of the three shot areas (2FG, 3FG, and FT), except for players who made a small number of goal attempts, analysis was conducted using data from a one-sided 95% confidence interval (Table 1). The number of samples for 2FG, 3FG, and FT were 133, 101, and 121 players, respectively. A one-way analysis of variance (ANOVA) and multiple comparisons (Bonferroni method) were performed to test the difference in mean height between the three shot areas (Table 2).

Table 1 Number of goal attempts and confidence intervals (317 players)

Shot areas	*M*	*SD*	*Min*	*Max*	*95%CI*
FG					
2FG	59.1	65.6	0	308	>53
3FG	20.4	32.6	0	218	>17
FT	15.2	20.0	0	116	>13

† 95% CI indicates the result of one-sided confidence interval.

Table 2 Characteristics of players and number of goal attempts

Shot areas	*n*	Player's height (m)				Goal attempts (times)			
		M	*SD*	*Min*	*Max*	*M*	*SD*	*Min*	*Max*
FG									
2FG	133	1.87	0.07	1.66	2.03	123.7	52.8	54	308
3FG	101	1.83*	0.06	1.66	2.00	57.5	35.8	18	218
FT	121	1.87	0.07	1.66	2.03	34.7	20.3	14	116

† *$p<0.05$ (showing the significant difference in the height of 3FG shooters when compared with that of 2FG and FT shooters using the Bonferroni method).

The league's shooting performance statistics are presented in Figure 1. For all 180 games, the total goal attempts were 18,729 (62.4%) for 2FG, 6,472 (21.6%) for 3FG, and 4,804 (16.0%) for FT (Figure 1A), whereas the total number of successful shots was 8,862 (63.2%) for 2FG, 1,925 (13.7%) for 3FG, and 3,232 (23.1%) for FT (Figure 1B). The most frequent shot area in relation to both goal attempts and shots made was 2FG. However, the highest SSR was for FT, followed by 2FG and 3FG, respectively (Figure 1C).

The number of players who attempted goals once or more during the season was 299 for 2FG, 224 for 3FG, and 233 for FT. Regarding successful shots (once or more) during the season, 282, 169, and 224 players successfully scored for 2FG, 3FG, and FT, respectively. In each of the three shot areas, a correlation analysis was conducted using data from a one-sided 95% confidence interval, except for players whose number of goal attempts was small (Table 1). The samples for 2FG, 3FG, and FT were 133, 101, and 121 players, respectively (Table 2). A one-way ANOVA showed a significant effect of shot area on height ($F_{(2, 352)} = 11.9$, $p < 0.01$, $\eta^2 = 0.06$), and the post-hoc test revealed that the mean height of the 3FG shooters was lower than that of 2FG shooters ($t_{(232)} = 4.42$, $p<0.05$, $r = 0.28$) and FT ($t_{(220)} = 4.18$, $p<0.05$, $r = 0.27$) (Table 2). However, the minimal effect ($\eta^2 = 0.06$) apparent in the one-way ANOVA and the small size effect ($r = 0.28$ and $r = 0.27$) in the post-hoc test indicate that the difference derived from player height between the three shot areas was trivial.

Figure 2 shows the relationship between player height and SSR for each shot area. In relation to 2FG, SSR increased for taller players ($r = 0.38$, $p<0.05$, in a two-tailed test). The coefficient of regression was 39.4. In other words, SSR increased 0.394 percent per centimeter of increase in height. Meanwhile, no positive correlation was observed for 3FG or FT. In particular, for FT, SSR decreased with any increase in player height ($r = -0.31$, $p<0.05$, in a two-tailed test).

For each of the 114 players with data for both FT and 2FG analyses, the difference between FT and 2FG SSRs

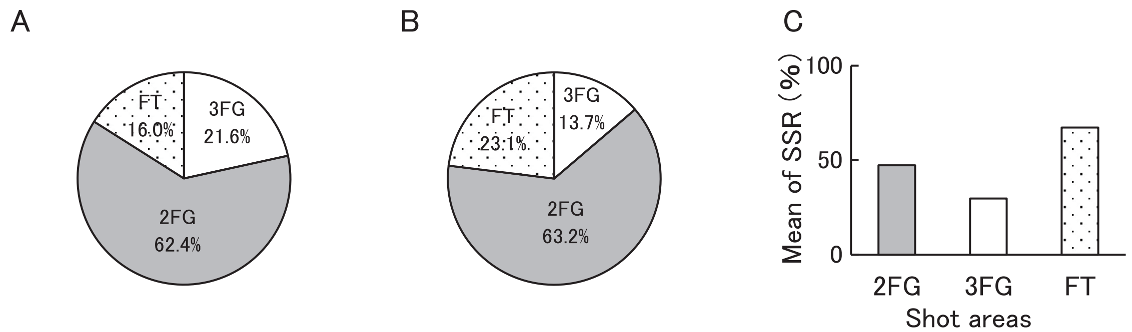

Figure 1　Statistics of shot performance in the 2013 Kanto Collegiate Basketball League Division 1-2.

† The two pie graphs show the ratio of goal attempts (A) and shots made (B). The bar graph is a comparison of the SSR between 2FG, 3FG, and FT (C). The filled, white, and dotted areas show the results for 2FG, 3FG, and FT, respectively.

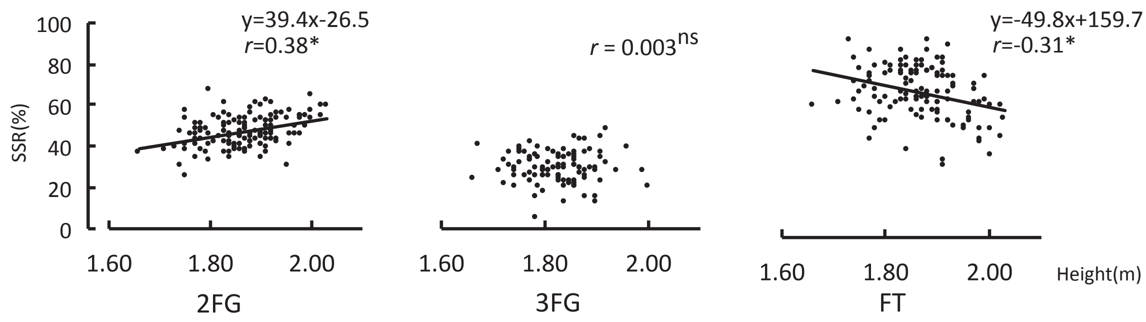

Figure 2　Relationship between player height and SSR for 2FG (left), 3FG (center), and FT (right).

† Correlation analyses were conducted for each shot area. The number of samples was 133 for 2FG, 101 for 3FG, and 121 for FT. *$p<0.05$.

(FT − 2FG) was calculated (i.e., the decrease in SSR for 2FG compared with that for FT). A negative correlation between player height and decrease in SSR ($r = -0.51$, $p<0.01$, in a two-tailed test) suggests that, for 2FG, taller players maintained better shooting performance than shorter players (Figure 3A). In addition, the study examined the relationship between player height and decrease in SSR for 3FG compared with that for FT ($n = 68$). However, no significant correlation was observed ($r = -0.03$, in a two-tailed test) (Figure 3B). Results of the multiple regression analyses for the SSRs for 2FG and 3FG revealed a difference in the explanatory variable. The 2FG SSR was explained by player height and FT SSR ($R = 0.44$, $p<0.01$), where player height ($\beta = 0.46$, $p<0.01$) had a stronger effect than FT SSR ($\beta = 0.21$, $p<0.05$) on 2FG SSR (Table 3). Meanwhile, 3FG SSR correlated with FT SSR ($r = 0.21$, $p<0.05$) only if the factor of player height was eliminated as an explanatory variable (Table 3). In the present study, the decrease in 2FG and 3FG SSRs compared to FT SSR was attributed to the difficulty in maintaining shot accuracy when in a 2FG or 3FG situation.

2. Relationship between player height and SSR in each of the five different shooting distances

In the shooting trials, shooters attempted goals from each of the five different shooting distances without the presence of any disturbance from opponents, as in the case for FT. Repeated measured one-way ANOVA showed that shooting distance had a significant effect on the mean SSR (Greenhouse-Geisser collection: $F_{(2.7, 94.1)} = 343.2$, $p<0.01$, $\eta^2 = 0.91$) (Figure 4). Multiple comparisons (the Bonferroni method) showed significant differences in all combinations of the mean SSR ($p<0.01$, $r>0.79$ in all combinations) (Figure 4). Namely, SSR declined when the horizontal shooting distance increased. In each of the five shooting distances, player height did not correlate with SSR (two-tailed test) (Figure 5).

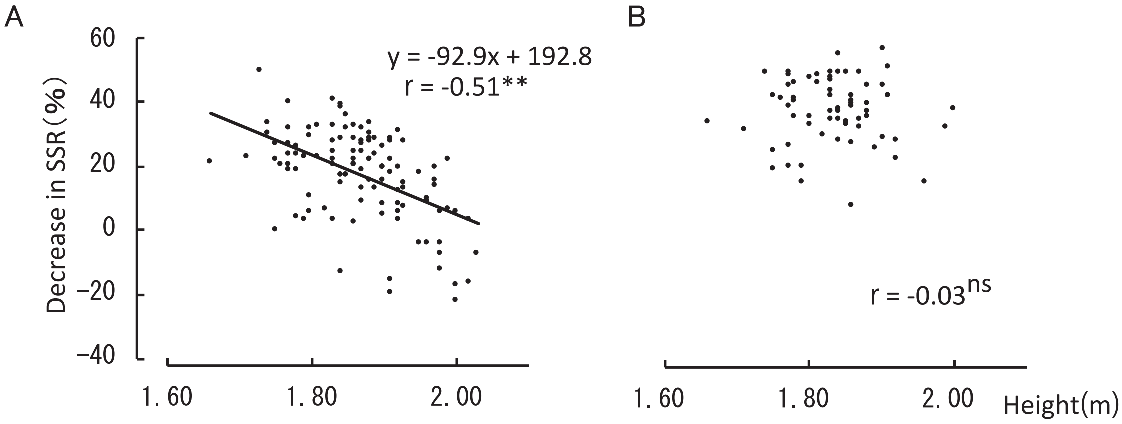

Figure 3 Relationship between player height and the decrease in SSR for 2FG (A) and for 3FG (B) compared with that for FT
**$p<0.01$.

Table 3 Results of multiple regression analyses for shot areas 2FG and 3FG

Explanatory variable	2FG		3FG	
	β	*r*	*β*	*r*
Player's height	0.46 **	0.39 **	0.04 *ns*	0.04 *ns*
SSR of FT	0.21 *	0.05 *ns*	0.22 *ns*	0.21 *
R	0.44 **		0.22 *ns*	
Adjusted R2	0.18		0.02	
n	114		73	

† These columns present the results of a multiple regression analysis for shot areas 2FG and 3FG. The standard partial regression coefficient and correlation coefficient are shown above the broken line.
**$p<0.01$, *$p<0.05$.

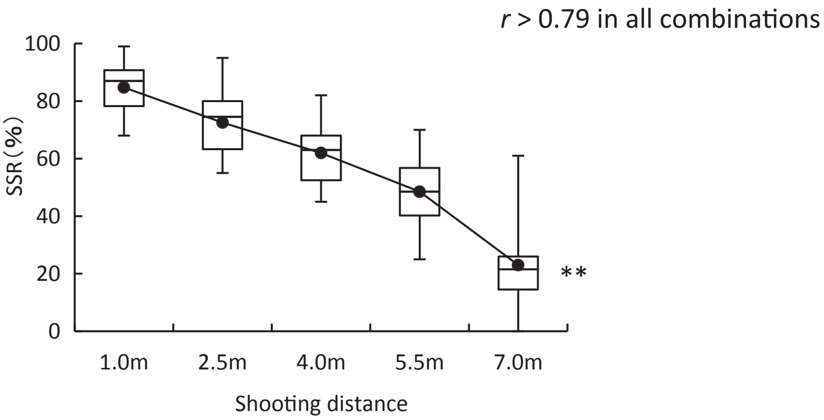

Figure 4　Comparison of the SSR at each point of five horizontal shooting distances

† Mean SSRs are shown by box and whisker plots, with the bottom and top of the boxes indicating the first and third quartiles, respectively, and the band inside the box representing the second quartile. The end points of the whiskers (vertical lines from the box) represent the minimum (the value of the bottom player) and maximum (the value of the top player) of the SSR at each shooting distance. The line plot shows the mean SSR of all 36 players at each shooting distance. Asterisks indicate a significant effect of shooting distance. ** $p<0.01$.

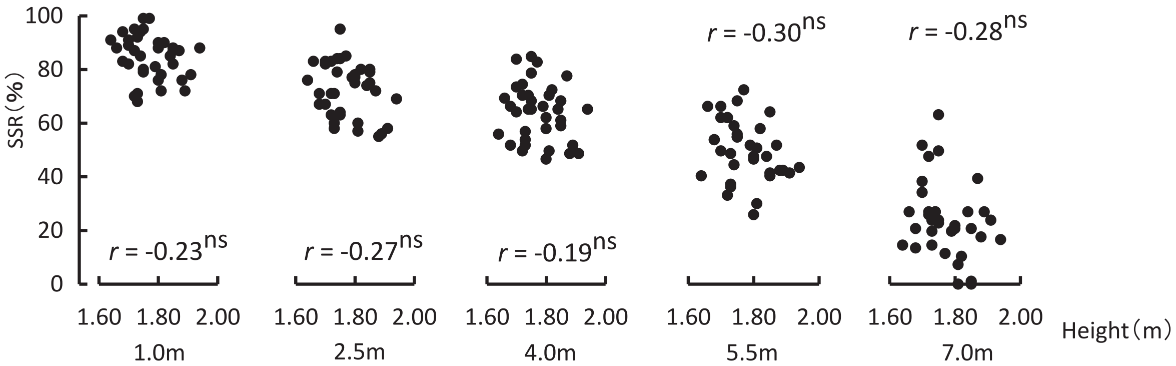

Figure 5　Relationship between player height and SSR at each shooting distance

† Each plot represents the data for each player.

Ⅳ. DISCUSSION

The present study examined whether it is easier for taller players to make successful shots than it is for shorter players. FGs attempted from inside and outside the area of the three-point line (i.e., 2FG and 3FG) are worth two and three points, respectively. In actual games, the SSR tends to be smaller for 3FG than for 2FG (e.g., Tsankov and Tsankova, 2013). The SSR in the present study showed a similar tendency (Figure 1C). This means that our samples have the same trend as a typical basketball game.

Previous studies reported that the probability of making a shot increases with an increase in release height (Brancazio, 1981; Mortimer, 1951; Maugh, 1981), suggesting that taller players have a theoretical shooting advantage. However, in actual games, SSR increased in taller players only for 2FG (Figure 2). This result means that the advantage of the taller players is limited.

On one hand, taller players tend to maintain a better shooting performance in 2FG when compared with shorter players (Figure 3A); on the other hand, no positive correlation between player height and SSR was observed for FT or 3FG (Figure 2). In particular, FT SSR decreased with increases in player height. As FT is attempted without any disturbance by opponents, FT SSR more directly reflects a player's ability to make an accurate throw. These findings suggest that, in our study, the shot accuracy was lower in taller players than shorter players. The SSR declined when the horizontal shooting distance increased (Figure 4). Previous studies have reported that the SSR decreases with an increase in the horizontal shooting distance from the basket (Okazaki and Rodacki, 2012; Bunn, 1972; Elliott, 1992). This decrease is mainly caused by a smaller horizontal angle and a greater shooting distance (Okazaki and Rodacki, 2012). Moreover, a positive correlation between player height and SSR was not observed in the shooting trials (Figure 5). Thus, from all shooting distances, taller players do not seem to hold an advantage in shots taken without interference from their opponents. Although the shot accuracy of taller players tended to be inferior to that of shorter players, the 2FG SSR increased for taller players. Hence, taller players have a strong advantage in 2FG.

The shooting position of FT lies within the 2FG area. Therefore, in terms of the relationship between player height and SSR, the inverse trend between 2FG and FT cannot be attributable to shooting distance. In attempting a field goal, players shoot against opponents (i.e., the defense). To stave off opponents, shooters tend to attempt to project the ball more quickly and from a greater height (Rojas et al, 2000). Taller players have a better chance of making such a shot without the ball being intercepted by their opponents. The shooting performance for 2FG for shorter players tended to be impaired by their opponents (Figure 3A). The present results suggest that the positive correlation between player height and SSR for 2FG (Figure 2) is attributed to the ease with which taller players maintain their shooting performance in the presence of opponents during games compared to shorter players.

Meanwhile, player height did not correlate with 3FG SSR (Figure 2). The positive correlation between the SSRs in 3FG and FT (Table 3) suggests that, in actual games, the important factor in determining 3FG performance is shot accuracy rather than player height. Miller and Bartlett (1993) examined the effect of increased shooting distance on shooting performance and shooting movement in relation to the jump shot and found that the height of the jump at release tended to decrease as the shooting distance increased. They noted that, "the desire for increased accuracy when releasing the ball further from the floor would seem to be overridden by the need to utilize the body's upward movement to help give force to the ball" (Miller, S. and Bartlett, 1993). Moreover, for long-range shots, taller players attempt a goal while maintaining ground contact in order to project a ball at an appropriate release speed, although this is still considered a jump shot (i.e., shooters release the ball prior to take off) (Miller, S. and Bartlett, 1996). These reports indicate that height advantage is negated in long-range shots, such as 3FG.

The limitation of this study was that we could not quantify the height of the shot release regarding the advantages of the taller players. One avenue for future research includes investigating what factor contributing to the shot success probability of the taller players is needed. The present study was limited to the data of the participants' height, which ranged from 1.65m to 2.06m and did not investigate release height. Further research is required to determine what factor contributes to the scoring advantage of much taller players, who can release a ball at a height above the target basket.

As a suggestion regarding potential areas for coaching, taller players are said to have an advantage in a basketball competition, but the results of this study suggest that coaches can consider that the advantageous characteristics of taller players appear in the 2FG shot scene as effective team tactics.

V. CONCLUSION

This study examined whether the perceived correlation between height and shooting advantage in basketball is valid. The main conclusions are as follows.

(1) A positive correlation ($r = 0.38$, $n = 133$) was witnessed between SSR and height only in the 2FG shot area during a game. The tall player's advantage was in his ability to withstand outside influences from other players, having shown a negative correlation ($r = -0.31$, $n = 121$) between height and FT SSR.

(2) In conditions where outside influence from other players was eliminated, the main effect on SSR proved to be distance and not height.

Taller players have a theoretical shooting advantage in basketball (Brancazio, 1981; Mortimer, 1951; Maugh, 1981). However, this advantage may not lead directly to better performance by taller players compared with shorter players. In terms of the relationship between player height and SSR, a positive correlation for 2FG and negative correlation for FT (Figure 2) suggest that taller players have a strong advantage only in relation to 2FG, and that this advantage is attributed not to the higher release point of taller players but rather to their being less affected by their opponents.

Ⅵ. ACKNOWLEDGEMENTS

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バスケットボール競技における長身者のフィールドゴールでの有利性

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和文抄録

本研究は，バスケットボール競技の得点場面における長身者の有利性の有無を検証した．関東大学バスケットボール連盟リーグ戦（2013年度）の公式記録（全選手317名）をもとに，フリースロー（FT），2ポイントフィールドゴール（2FG）及び3ポイントフィールドゴール（3FG）のそれぞれで，身長とショット成功確率（SSR）の相関関係を調べた．その結果，2FGにおいてのみ，身長が高いほどSSRが高かった．本研究では，さらに，対戦相手の妨害を受けないFTに着目し，36名のバスケットボール熟練者で，バスケットまでの距離が異なる条件下において身長とSSRの相関関係を調べた．しかし，2FGエリアから3FGエリアに至る5段階（1.0mから7.0mまで）のいずれの距離においても，長身者のショット成功確率が高いことを示す相関関係は確認されなかった．これらの結果は，バスケットに近い（2FG）エリア内で，且つ対戦相手との競い合いの中で放つショット場面においてこそ，長身者の強い有利性が発揮されることを示唆する．

キーワード：バスケットボール，身長，フィールドゴール，フリースロー