Paper : Coaching

Is it possible to improve collegiate soccer players' jump ability? —A comparison of soccer and volleyball players' jump height, arm swing, and body crouch in vertical and header jumps

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This study aims to clarify the differences between soccer and volleyball players in jump height and jump motion (arm swing and body crouch) in vertical and header jumps with a running start, and the relationships among the parameters. The participants were 35 male Japanese university soccer players and 37 male Japanese university volleyball players. The jump height and jump motion variables (extension angle of the shoulder joint just before the jump and extent of body flexion just before the jump) were significantly higher in volleyball players than those in soccer players in both types of jumps. The growth of jump height, which is a value that subtracts the jump height of the vertical jump from that of a header jump, was significantly higher for volleyball players than soccer players. The significant multiple correlation coefficients between the jump motion variables and jump height was found both in a vertical jump and in a header jump (vertical jump: $r = 0.43$, $r^2=0.19$; header jump: $r = 0.62$, $r^2=0.38$). In conclusion, volleyball players jump higher than soccer players in vertical and header jumps with a running start because volleyball players conduct a rational jump motion using both arm swing and body crouch. There is sufficient room to improve soccer players' jump ability, and soccer players can benefit from improvement in jump motion (arm swing and body crouch).

Keywords: Soccer, Jump motion, Arm swing, Body crouch, Jump height

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1. Introduction

One of the skills that soccer players use during a game is a jumping header. It is a technique in which a player hits the ball with the center of the forehead while jumping. During the header, the player moves his head and shoulder backward, bends his knee, and then moves his head, shoulder, and legs forward as he hits the ball (National Soccer Coaches Association of America, 2006). Generally, although the frequency at which soccer players perform a header jump during a game is low compared to kicking, trapping and dribbling the ball, a header jump is also an important skill because it may affect a game's outcome. Although a few studies regarding header examined the effect of header on the brain (Kirkendall et al., 2001; Putukian, 2004), there are very few studies that are useful to a coach when he is teaching a skill.

Soccer players frequently compete with opponents in air during a jumping header. To win the competition with an opponent, it is important to jump high. A player who achieves longer flight duration by jumping high can keep his body well-balanced in the air and perform more accurate headers. However, header jumps are not practiced regularly because the frequency of a header jump during a game is low.

We conducted a questionnaire analysis on jumping headers targeting 26 male collegiate soccer players, each having more than 9 years soccer experience in 2012. The percentage of the players who have never been taught jumping header techniques by a coach was 73.1%, and the percentages of those who consider the amount of jumping header training to be low was 84.6%. From this pattern, it is clear that some soccer coaches do not emphasise on a jumping header. Hence, even if soccer players have long-term soccer experience, they have little jump training experience. For this reason, it is possible that they neither have superior jump ability nor utilise their jump ability to perform a jumping header.

On the other hand, volleyball players have superior jumping ability. Jump ability is important for volleyball players because they have many opportunities to jump, specifically to attack and block during a game (Ziv & Lidor, 2010). They frequently practice jump training and are instructed on jump skill by their coaches. Because of the different experiences in which a player receives instruction about a jump and the quantity of jump training, it is hypothesised that volleyball players have superior jump ability over soccer players. It is also supposed that volleyball players can jump high in a header jump with a running start, which soccer players do, because volleyball players always jump with a running start for an attack. In addition, there may be a difference between the players in jump motion, and volleyball players may conduct more rational and efficient jump motion compared to soccer players. Namely, it is possible that volleyball players jump with a recoil motion such as arm swing and body crouch. Problems faced by soccer players regarding jump ability and jump motion will become clear by comparing the players' jump ability and jump motion. The results of this study will enable soccer coaches to realize the importance of training for vertical and header jumps and will improve their instruction ability.

This study aims to clarify the differences between soccer and volleyball players in jump height and jump motion (arm swing and body crouch) of vertical and header jumps with a running start and the relationships among the jump motion and jump height. In addition, this study uses these results to examine the scope for improvement in jumping abilities of collegiate soccer players.

2. Methods

2.1. Participants

The participants were 35 male Japanese university soccer players and 37 male Japanese university volleyball players. All of them had at least three years of athletic experience, and the total years of experience were 11.5 ± 2.0 for soccer players and 7.7 ± 2.1 for volleyball players; hence, both soccer and volleyball players had long-term athletic experience. **Table 1** shows the characteristics of the participants

Table 1 Characteristics of the participants and test results of the differences between the players for each variable

		Soccer (n=35)	Volleyball (n=37)	t	p
Age	MEAN	19.5	19.4	0.55	0.58
(years)	SD	1.1	1.0		
Height	MEAN	171.9	175.7	−2.85 *	0.01
(cm)	SD	5.8	5.4		
Body mass	MEAN	64.8	68.3	−2.07 *	0.04
(kg)	SD	6.8	7.4		
Years of experience	MEAN	11.5	7.7	7.86 *	0.00
(years)	SD	2.0	2.1		
Knee extension muscle strength	MEAN	43.3	47.1	−1.81	0.07
(kgf)	SD	8.0	10.0		

*: $p<0.05$

and the results of the differences between the players for each variable. Significant differences were found in height, body mass and years of experience.

μTas·F-1 (ANIMA, Japan) was used to measure knee extension muscle strength. The greatest isometric muscle strength, obtained when the participants were sitting with a knee angle of 90 degrees, was measured twice for each leg. The band attached to the measurement device was rolled round the chair leg and the participant's ankle and fixed so that the measurement device did not move. Because the reliabilities between the trials were high (intra-class correlation coefficient (ICC) was 0.95 in both legs) and a significant difference between both legs was not found, the average value of both legs, which was calculated from that of two trials for each leg, was used for the analysis.

The purpose and methods of the study were explained to the participants, and informed consent was obtained from them before taking the measurements. The experimental protocol was approved by the Ethics Committee on Human Experimentation of Faculty of Human Science, Kanazawa University (2012-06).

2.2. Measurement method

The jump motion for each participant was recorded by a video camera (HDC-TM300, Panasonic, Japan). Before the jump trial, markers for video analysis were attached to the participants' bodies. All points except the glabella were put on the left side of the body. Four points (the glabella, acromion, elbow, and iliac crest) were used for analysis. To analyse the joint angle on the sagittal plane, the participants stood sideways for the video camera so that the left side of the body was facing the camera. Next the participants performed vertical and header jumps two times each. They were instructed to jump as high as possible and jump with both-legs on takeoff. In the vertical jump, a general method was used. The participants jumped on the spot, directly upward. Recoil motion (the use of arm swing and body crouch) was permitted. In the header jump, the running start distance was set under 5 m. They did not practically head a ball during the header jump, but were rather instructed to jump as if they intended to head a ball. If they had indeed headed a ball during the measurement, there is a possibility that they would not have performed their best possible (highest) jumps because they would have to jump according to the timing of the approaching ball. Hence, the condition without a ball was selected.

In addition, they were instructed to jump with their profiles facing the camera as much as possible. When the participant could not perform these instructions, the trial was judged a failure and canceled, and a remeasurement was conducted.

Motion analysis software (Dartfish, Dartfish Japan) was used to calculate the following evaluation variables. The software can calculate the distance, angle, and time using the recorded video. The data from the video were analyzed at 30 Hz.

2.3. Evaluation variables

Evaluation variables included jump height, extension angle of the shoulder joint before a jump, extent of body flexion before a jump in the vertical and header jumps (**Figure 1**), growth of jump height and growth rate of jump height (**Figure 2**). Jump height is the distance (cm) that subtracts the height of the glabella at standing from the height of the glabella when a jump is at its highest point. The extension angle of the shoulder joint is its maximum extension angle just before a jump. The extent of body flexion is the value (%) of the distance that subtracts the height of the glabella at the maximum flexion of the body just before a jump from the height of the glabella at standing, divided by height. The extent of body flexion was selected as the variable used to evaluate body crouch. The extension angle of the shoulder joint before a jump and the extent of body flexion before a jump are defined as jump motion variables. These motion variables were selected because they could evaluate typical motions affecting jump height, as attested in previous studies. Many studies have reported that arm swing affects jump height (Shetty & Etnyre, 1989; Harman et al., 1990; Feltner et al., 1999; Lees et al., 2004; Hara et al., 2006, 2008B). In addition, body crouch, which triggers recoil motion, also affects jump height because jump height is higher in a countermovement jump than in a squat jump (Harman, et al., 1990; Bobbert et al., 1996; Bobbert & Casius, 2005; Hara et al, 2008A). The simplest and easiest variables were chosen to make it easy for soccer leaders (coaches) to understand the study results. The growth of jump height is a value (cm) that subtracts the jump height in the vertical jump from that in the header jump. The growth rate of jump height (%) is the rate of jump height in the

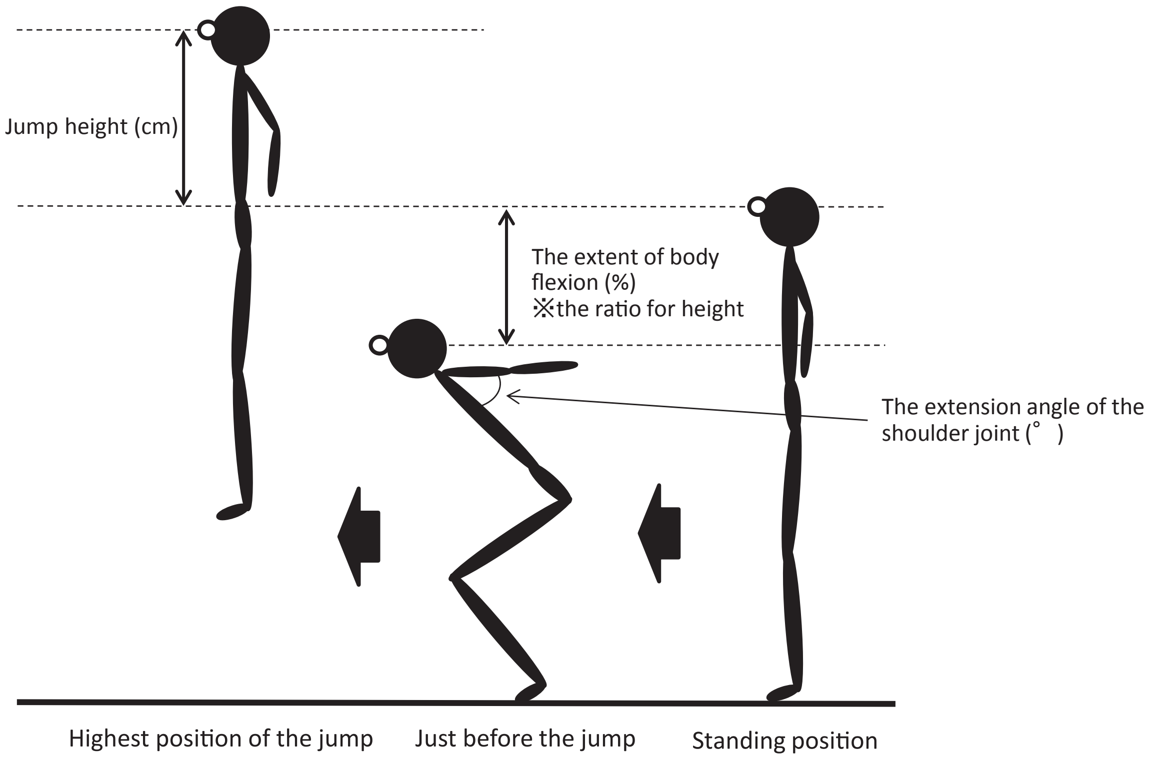

Figure 1 Evaluation variables (jump height, the extent of body flexion, and the extension angle of the shoulder joint)

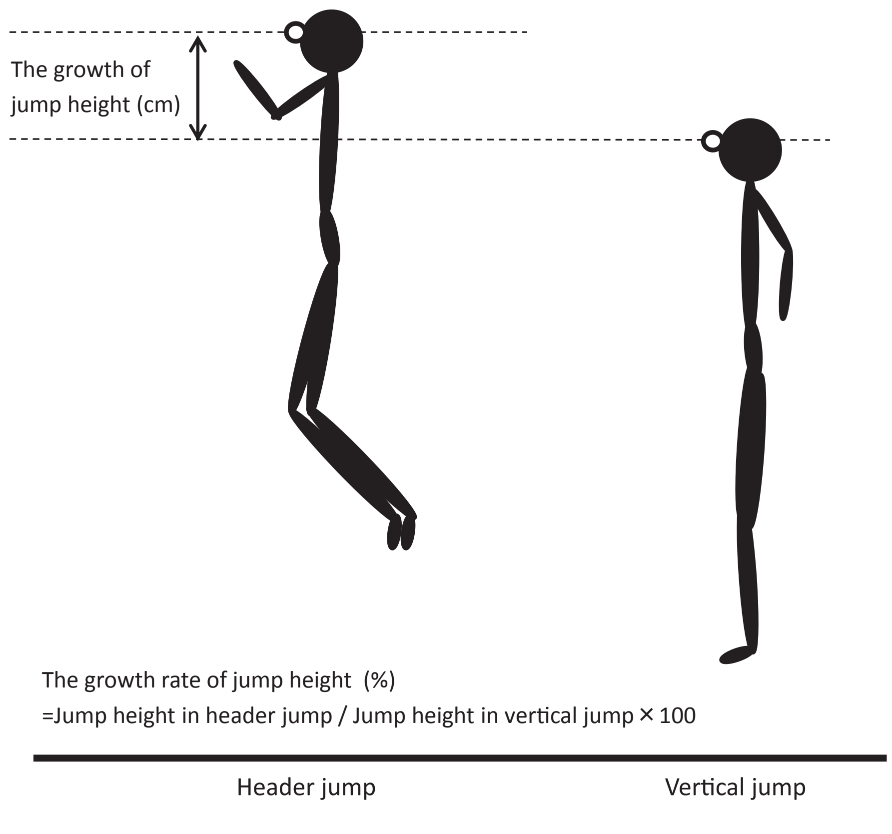

Figure 2 Evaluation variables (the growth of jump height and the growth rate of jump height)

header jump for the jump height in the vertical jump. These two variables show the extent of growth of jump height in the header jump for jump height in the vertical jump. Namely, they were used to determine whether participants could apply their initial vertical jump ability to a header jump with a running start. It is judged that participants could incorporate a running start and their initial jump ability if the values of these variables were high.

2.4. Statistical analysis

Intra-class correlation coefficients were calculated to examine trial-to-trial reliability for jump height, extension angle of the shoulder joint, and extent of body flexion. An unpaired t-test was used to test the differences between the soccer and volleyball players for each variable except for the growth rate of jump height. If a significant difference was found, the effect size (Cohen's d) was calculated. To examine the relationships among the jump motion variables and jump height, Pearson's correlation coefficients were calculated. In addition, multiple regression analysis was performed, and the determination coefficients were calculated to examine the effect of the jump motion variables on jump height. The level of statistical significance was set at $p < 0.05$. IBM SPSS statistics 17.0 was used for the statistical analysis.

3. Results

Intra-class correlation coefficients (ICCs) in vertical jump included 0.95, 0.82, and 0.88 for jump height, extension angle of the shoulder joint, and extent of body flexion, respectively. Intra-class correlation coefficients (ICCs) in header jump included 0.93, 0.87, and 0.93 for jump height, extension angle of the shoulder joint, and extent of body flexion, respectively. **Table 2** shows the results of the differences between the players for each variable. Volleyball players showed significantly higher values than soccer players in jump height, the extension angle of the shoulder joint, and the extent of the body flexion in both jumps. The effect sizes between soccer and volleyball players in jump height, extension angle of the shoulder joint, and extent of the body flexion were 1.19, 0.89, and 1.63 for the vertical jump and 2.08, 0.48, and 1.90 for the header jump, respectively. The growth of the jump height was significantly higher in volleyball players than in soccer players, and the effect size was 0.61. The growth rate of jump height was 119.1 ± 20.7% and 125.0 ± 22.2% for soccer and volleyball players, respectively. **Figure 3** shows an example of differences in arm swing and body crouch just before a vertical jump between the players, and **Figure 4 and 5** show their different positions before a header jump.

Table 3 shows the relationships between the jump motion variables and jump height. In a vertical jump, significant correlation coefficients were found

Table 2 Results of the differences between the players for each variable

			Soccer (n=35)	Volleyball (n=37)	t	p	ES
Vertical jump	Jump height (cm)	MEAN	45.9	56.8	−5.10 *	0.00	1.19
		SD	8.1	9.9			
	The extension angle of the shoulder joint (°)	MEAN	54.2	67.5	−3.83 *	0.00	0.89
		SD	15.4	14.1			
	The extent of body flexion (%)	MEAN	31.4	42.5	−7.01 *	0.00	1.63
		SD	6.4	6.9			
Header jump	Jump height (cm)	MEAN	53.3	69.6	−8.94 *	0.00	2.08
		SD	5.3	9.5			
	The extension angle of the shoulder joint (°)	MEAN	75.3	83.0	−2.08 *	0.04	0.48
		SD	13.9	17.1			
	The extent of body flexion (%)	MEAN	14.3	22.9	−8.19 *	0.00	1.90
		SD	4.6	4.3			
The growth of jump height (cm)		MEAN	7.4	12.8	−2.61 *	0.01	0.61
		SD	6.5	10.4			

*: p<0.05, ES: effect size

Figure 3 An example of differences in arm swing and body crouch just before a vertical jump between a volleyball player (left) and a soccer player (right)

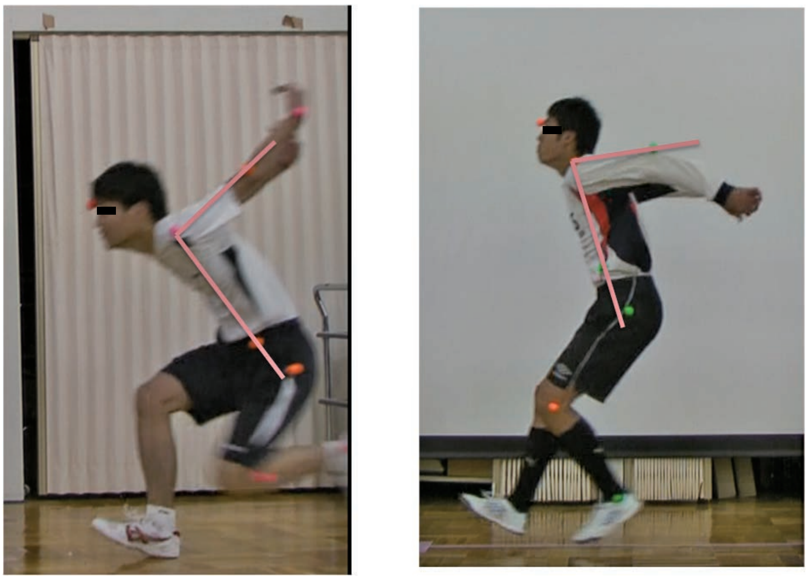

Figure 4 An example of differences in arm swing just before a header jump between a volleyball player (left) and a soccer player (right)

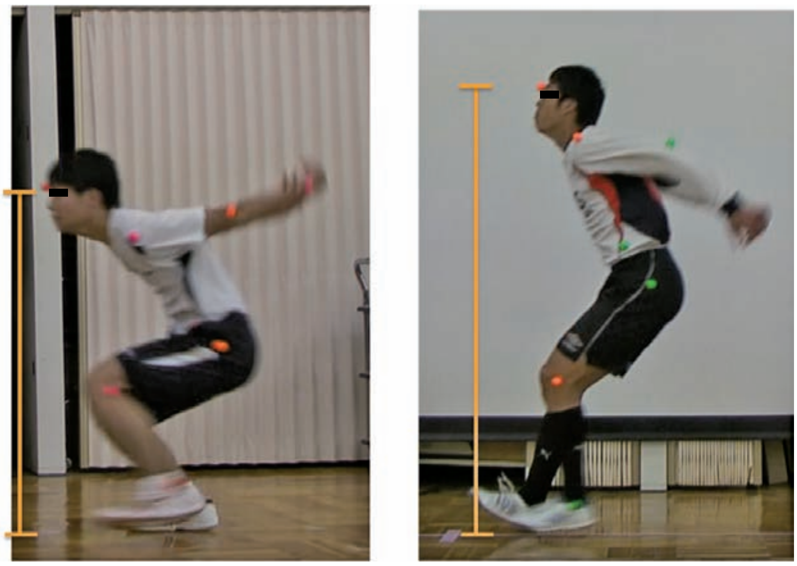

Figure 5 An example of differences in body crouch just before a header jump between a volleyball player (left) and a soccer player (right)

between the extent of body flexion and jump height. In a header jump, significant correlation coefficients were found between the extension angle of the shoulder joint and jump height and between the extent of body flexion and jump height.

Tables 4 and **Table 5** show the results of the multiple regression analysis. The significant multiple correlation coefficients between the jump motion variables and jump height were found in a vertical jump and in a header jump (vertical jump: $r = 0.43$, $r^2 = 0.19$; header jump: $r = 0.62$, $r^2 = 0.38$).

4. Discussion

Because the reliability of a variable is good when intra-class correlation coefficients are over 0.7 (Jackson et al., 1980), the reliability of all variables in this study are considered to be high.

Volleyball players jumped higher in the vertical jump than soccer players. Volleyball players have many opportunities to jump, such as while attacking and blocking in practice and during a games. Tillman et al. (2004) reported that a volleyball player jumps 45 times on average and up to 73 times in two sets of a game. The jump ability of volleyball players also differs by competition level; a player at high competition level can jump higher than one at low competition level (Fleck et al., 1985; Forthomme et al., 2005). Volleyball players routinely need to jump high; therefore, they frequently perform jump exercises and are taught how to jump by coaches at daily training. On the other hand, soccer players generally do not perform jump exercises, as previously noted, because they do not have as many opportunities to jump during play as volleyball players, and the importance of jumps differs in soccer and volleyball. It is inferred that the differences in the frequency of jump training and the importance of the jump affected the differences between the players' jump ability.

Although a header motion is unique to soccer players, volleyball players jumped higher than soccer players in the header jump. The volleyball players likely performed a header jump while applying an attack motion with a running start, which they frequently practice. Incidentally, it is not clear whether they are good at header because the participants did not practically perform header. However, if one can jump high and with long jump flight duration, one is more likely to successfully complete a jumping header: such jumps enable one to head a ball at higher positions and obtain the space needed for head in air by jumping earlier than an opponent. Obtaining header space also allows more effective control of the ball. Hence, it is important for soccer players to jump high and with long jump flight duration, and thus, it would be desirable for them to be able to jump with the same proficiency as volleyball players.

The effect size between the players in jump height in the vertical jump was 1.19 and the one in the header jump was 2.08. In addition, the growth of jump height, which subtracts the jump height in the vertical jump from that in the header jump, was larger in volleyball players (12.8 cm) than in soccer players (7.4 cm). These results infer that soccer players were inferior to volleyball players in their initial jumping ability (jump ability at a vertical jump), and the tendency was more prominent in header jumps than in vertical jumps. Volleyball players could exert their vertical jump ability in the header jump with a running start. On the other hand, soccer players could not do that. In addition, the growth rate of jump height, which shows the growth of the jump height in the header jump for the jump height in the

Table 3 Relationships between jump height and jump motion variables

		The extension angle of the shoulder joint	The extent of body flexion
Vertical jump			
Jump height	r	0.14	0.43*
	p	0.25	0.00
Header jump			
Jump height	r	0.31*	0.58*
	p	0.01	0.00

*: $p<0.05$

Table 4 Results of multiple regression analysis of calculating jump height from jump motion variables in a vertical jump

Variables	B	SEB	β		r
The extension angle of the shoulder joint	−0.03	0.08	−0.04		0.14
The extent of body flexion	0.55	0.14	0.45	*	0.43
constant (intercept)	32.7	5.68			
SEE	9.64				
R	0.43				
R^2	0.19				

B: Standardized coefficient, SEB: Standard error of regression coefficient
β : Standard partial regression coefficient, r: Correlation coefficient
SEE: Standard error of estimate value, R: Multiple correlation coefficient
R^2: Determination coefficient, *: $p < 0.05$

Table 5 Results of multiple regression analysis of calculating jump height from jump motion variables in a header jump

Variables	B	SEB	β		r
The extension angle of the shoulder joint	0.15	0.07	0.21	*	0.31
The extent of body flexion	0.99	0.18	0.54	*	0.58
constant (intercept)	31.4	5.81			
SEE	8.93				
R	0.62				
R^2	0.38				

B: Standardized coefficient, SEB: Standard error of regression coefficient
β : Standard partial regression coefficient, r: Correlation coefficient
SEE: Standard error of estimate value, R: Multiple correlation coefficient
R^2: Determination coefficient, *: $p < 0.05$

vertical jump, was 119% and 125% for soccer and volleyball players, respectively. Although volleyball players improved 25% in their header jumps with respect to their jump heights of vertical jump, soccer players showed only 19% improvement. This result also proves that soccer players could not apply their initial jumping ability to jumps with a running start. The average value in the soccer players' experience was 11.5 years. Hence, they had enough experience. However, the results of the jump ability in soccer players were not good, as stated above. The results reveal a serious problem for soccer players, showing a need for them to improve their jumping skills. The header jump is an important skill that could affect the result of a soccer game. Hence, it will be necessary to conduct jump training in coaching. In particular, coaches who instruct young soccer players should actively incorporate jump training because even soccer players who have trained from childhood lacked good jumping abilities. In addition, it is necessary to accumulate the findings from a study that can alter the coach's feeling for the header jump or jump motion. Very few studies have been conducted on header jumps or improvement of jump ability in soccer players. In the future, it will be necessary to perform the motion analysis of a jumping header, teaching methods for header, and valid training methods for the improvement of jumping ability.

Volleyball players were able to jump high in header jumps because of their regular practice in the attack jump. Certainly, their jumping ability has been improved by their specialized jump training. Therefore, the jump ability of soccer players may improve by utilising jump training, which volleyball players always do. It will be necessary to examine the effect of the jump training that volleyball players practice on the jump ability of soccer players.

Jump motion also differed between the players (**Table 2, Figure 3, Figure 4 and Figure 5**). In both jumps, the volleyball players swung their arms and crouched more just before a jump, compared to soccer players. Significant relationships among the jump motion variables and jump height except for between the extension angle of the shoulder joint and jump height in vertical jump were found (**Table 3**). Take-off velocity is important when jumping high (Feltner et al., 1999). It has been reported that the velocity improves by 6–10% by an arm swing (Shetty

& Etnyre, 1989; Harman et al., 1990; Lees et al., 2004; Hara et al., 2006, 2008A, 2008B; Wagner et al., 2009). Hara et al. (2006) reported that arm swing increased the amount of work exerted by hip and ankle joints. In addition, Lee et al. (2004) reported that arm swing also increased the energy released from muscle and tendon near the ankle, knee and hip joints. Thus, it is inferred that volleyball players can increase the amount of work performed by the lower extremities and improve their take-off velocity by an arm swing. In addition, jump motion is a stretch-shortening cycle (SSC) movement (Komi, 2000), and using SSC efficiently is important to jump high. Body flexion before a jump is important from the viewpoint of SSC because the elastic energy is produced by stretching muscles and tendons. Specifically, the muscles and tendons related to the large joints (hip, ankle, and knee) were stretched and exerted large power because the hip, ankle, and knee joints were mainly engaged in the body crouch. It is inferred that volleyball players achieve appropriate SSC movement by bending down before a jump and perform a rational jump motion. In addition, it is suggested that body flexion is more important than the extension angle of the shoulder joint because the correlation coefficients of jump height are higher for the extent of body flexion than for the extension angle of the shoulder joint.

Both the extension angle of the shoulder joint and the extent of body flexion can explain the 19% and 38% improvement in the jump height of vertical jump and the jump height of header jump, respectively (**Table 4 and Table 5**). Hence, improvements in jump motion (arm swing and body crouch) may result in better jump performance in soccer players. Thus, it is important for soccer coaches to teach arm swing and body crouch during header jump training instructions. The characteristic of the athletic event differs between soccer and volleyball in the form of their play. For example, while a soccer player often directly confronts opponents, a volleyball player does not. Some people may believe that soccer players cannot jump like volleyball players. However, a soccer player has opportunities to jump when there is no opponent nearby (i.e., when they are “free” at a running start) and when confronting opponents only in the air. In this situation, they should be able to jump like volleyball players. In header, a soccer player who is able to jump high can successfully beat an opponent when competing for a header. Hence, soccer players should learn and practice methods for jumping.

In this study, only body flexion and arm swing were evaluated; each joint angle could not be evaluated. Wagner et al. (2009) conducted motion analysis of spike jumps in volleyball players and reported that knee flexion–extension angle before a jump is closely related to jump height. Because each joint angle affects a jump motion, detailed motion analysis of jump motion will be necessary in future.

5. Practical Applications

- Soccer coaches notice that there is sufficient room to improve in the jumping ability of soccer players even if they have long-term soccer experience.
- Soccer coaches strongly recognize the importance of the instruction of header jump.
- Each soccer coach will learn the instruction method of header jump or jump motion.

6. Conclusion

This study examined the differences between soccer and volleyball players in jump height and jump motion (arm swing and body crouch) in vertical and header jumps. Volleyball players jumped higher in both jumps than soccer players. It was inferred that the arm swing and crouch of the body were factors that contributed to the above differences. Soccer players did not utilise their innate jump ability in header jumps. It is concluded that there is sufficient room to improve in the jumping ability of soccer players even if they have long-term soccer experience. Thus, during header jump instructions, soccer coaches should emphatically inform players about the importance of arm swing and crouching before a jump.

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