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# Kinetic Comparison and Analysis between the Basketball Set Shot of Skilled and Unskilled Basketball Players

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# 농구 세트 슛의 숙련자와 비숙련자간 운동역학적 비교 분석

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**<ABSTRACT>**

This study kinetically analyzes and describes a basketball set shot movement to understand the mechanism. The study intends to provide source data for teachers and students who want to analyze basketball set shot movement scientifically. To achieve the purpose of this study, a total of 12 subjects, including 6 skilled and 6 unskilled basketball players participated. The basketball set shot movement, from knee joint reaching its minimum angle to the ball leaving the hand, was analyzed. Mean kinetic variables related to the movement including angle, angular velocity, and ground reaction force were verified. In the skilled subjects, the shoulder joint angle was smaller when the knee joint was at the minimum angle and the elbow was at the minimum angle. The hip angle was large when the knee joint reached the minimum angle. The knee joint angle was small when the elbow reached the minimum angle. The elbow joint angular velocity was large when the elbow reached the minimum angle. The shoulder joint angular velocity was large when the elbow joint reached the minimum angle and when the ball left the hand. The hip angular velocity was large when the knee joint reached the minimum angle. The knee joint angular velocity was large when the ball left the hand. For the ground reaction force, the lateral ground reaction force acted outward the whole time on the right foot, and inwards when the ball left the hand on the left foot. The longitudinal ground reaction force acted backward when the knee joint was at the minimum angle on the right foot and acted backward when the elbow joint was at the minimum angle on the left foot. The vertical ground reaction force acted upward on the right and left foot when the knee joint was at the minimum angle and the elbow joint was at the minimum angle.

**Key words** : Free throw, set shot, kinematic, kinetic

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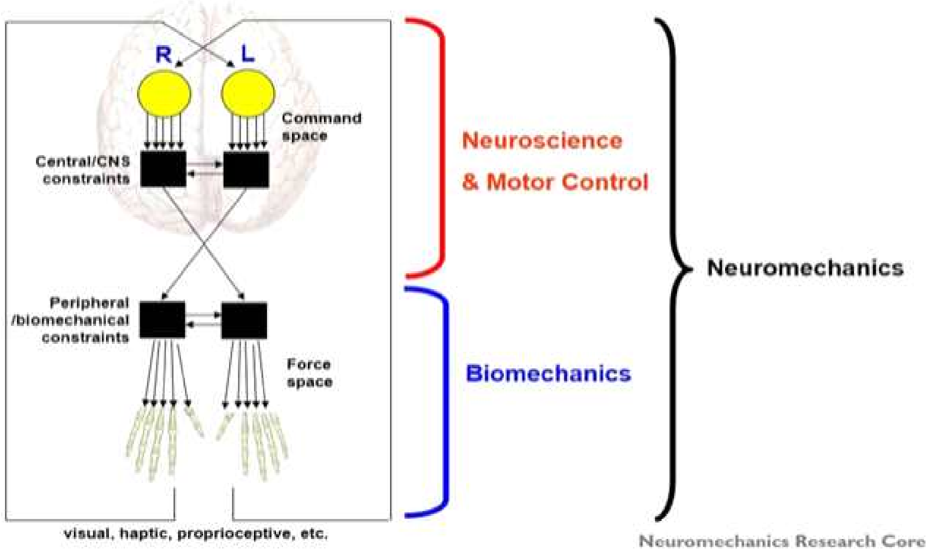
# I. Introduction

When Scottie Pippen misses a free throw, Michael Jordan jumps from the back and dunks the ball in the rim. I do not know whether he intended to miss the free throw, but he certainly intended to catch the bouncing ball in the air and finish it with a dunk shot. Likewise, scenes in all sports are created by moving the body instantly judging the opportunity in a short moment. People wonder how the intuitive judgment from animal instinct is made, but we know where that order of judgment is made. When that momentary judgment is made, the body carries out what it has to do within a very short time. Whether the information is presented visually or aurally, it is provided through the five senses, and the brain prompts the body to move through the process quickly determining the situation. The body that receives the signal physically resists the movement of air and other external forces on this planet. Besides, these physical movements can be measured in two types. Russell C. Hibbeler (2009) deals with kinematics only with aspects of motion and not concerning the causes of the movement, suggesting speed, angle, acceleration, and angular velocity, etc. explain the movement of bones in kinematics. 'Kinetics' is the addition of forces, torques, and masses to kinematics. Kinematics and kinetics are collectively called 'biomechanics'. The process of brain, thinking and judging, based on visual and tactile information is in the realm of 'Neuroscience' and 'Motor Control'. Moving according to the received information is in the realm of 'Biomechanics'. Shim (2019) unified such distinctly divided divisions into one and explained the convergence with 'Neuromechanics' [Figure 1]. The process of making a free throw decision in the brain and throwing a ball precisely to the edge of the rim is done through the detailed peripheral nerves up to the fingertips. The whole process where the ball bounces, flies and dunked with momentary, animal instincts and jumping powers should now be connected and studied as continuous feedback. These brain-based studies that start from brain commands may not only be the convergence of 'Neuroromechanics' but also into various fields. You can also develop various indicators and scales, such as brain-based reading ability diagnostic indicators or brain-based learning characteristics(Chae & Kwon, 2016; Lee et al., 2019). You can also study the effects of self-efficiency and self-concepts, working memory and attention-intensive forces through physical activity(Lee, An & Kim, 2019; Woo, Kim & An, 2019; Yun, Ho & Kim, 2019).

Among the basic techniques of basketball, the shot is both the best attack goal and the ultimate purpose that determine the outcome of the game (Pang, 1995). We see fantastic performances in basketball, such as passing passes and dribbling, but those are only processes. There is only one final purpose. It is a shot. As such, the shot is very important in basketball. Cooper and Siedentop (1975) pointed out that the most important and difficult to learn of basketball skills is shooting. Shooting is the ultimate target and ultimate goal, and a very important but difficult move. One point, two points, and three points goals go through the same rim, but score differently depending on distance or situation. Shooting includes jump shots, free throws, layups, and running shots. The most frequently used basic and important shots in the game are jump shots and free throws (Park & Choi, 1997). Jump shots are useful for scoring and avoiding defending and blocking opponents. The higher the jump, the better, and sometimes there is a fadeaway shot that jumps back high. A free throw is given when a foul occurs in the event of a shot or a team foul. Sometimes, a free throw at the end of the match is a very important shot for winning or losing.

A study by Goosey-Tolfrey, Butterworth, and Morriss (2002) found that 10-20% of the shots were scored by free throws in wheelchair basketball as well as regular basketball. The free throw is very important. The free throw is a shot that is allowed to throw in the most stable posture, as it is given because of the opponent's penalties. The player stands with two feet on the ground at a distance of about 4 meters from the basketball stand. A free throw shot during a game is categorized as set shot by its method of throwing a shot. A set shot is a contrasting concept to a jump shot, in which it is performed with two feet on the ground, making the shot very stable. It is also the first shot that is taught to those who are new to basketball. Therefore, among the shootings in basketball, the set shot is the most effective shot for comparing and analyzing the kinematic and kinetic mechanisms that occur after the brain commands to shoot. EEG(electroencephalogram) measurement is easy in free throws because it is a position with limited joint movement (Moon, 2017).

Accurate control and coordination of the human body, which are commanded by the brain, are necessary for accurate and successful shooting. Macauly (1970) reported that a wider area of palms should be in contact with the surface of the basketball to effectively control it. Wooden (1999) states that because the middle finger is very sensitive, it should contact the basketball as long as possible. Silverberg, Tran, & Adams (2011) studied the relationship between clean shots placed directly on the rim by controlling and coordinating upper body and bank shots hitting the backboard. They concluded that clean shots are 40cm longer than bank shots and studied the sensual control within the distance. Elliotte & Smith (1983) analyzed the correlation between shot accuracy and kinetic and anthropometric variables and reported that it was advantageous to have a tall, mesomorph body shape, high fat composition, and a strong elbow extensor. A successful element of the shot is how to throw the ball. Kirby and Robert (1985), in his study on projection angle and projection velocity of basketball, reported that the projection angle depends on the throwing distance and that the longer the shooting distance, the smaller the throwing angle. It was reported that the throw




**[Figure 1]** Neuromechanics (Shim, 2019) speed should be increased by the additional exercise of the forearm and wrist (Toyoshima, Hoshikawa & Ikegami, 1981). Factors that determine the success of the shot are throw height, throw speed, and throw angle. These factors are caused by interaction with the projection posture, and the type varies according to the physical characteristics of the athletes (Hayes, 1987). Projection angle, speed, and height depend on the coordination of joints that deliver kinetic energy to the musculoskeletal system (Mullineaux & Uhl, 2010). Brancazoi (1984) and Matin (1981) suggested that the ideal shooting is performed when the center of gravity is the highest. Ju (1989) suggested in free throws, the optimum speed is between 48.47 ~ 54.85 deg and the optimum projection speed is between 7.33 ~ 7.39 m / s. Likewise, the successful shot by using the projection angle, the velocity, the joint coordination, the control, and the senses is closely related to the angles of the upper and lower bodies, the angular velocity, and the force of the legs when the shot is thrown. Based on this theory, this study aims to contribute to the systematic, rational and scientific analysis of basketball set-shooting motions by comparing kinematic components including projection angles and angular velocities, and kinetic components including ground reaction forces of skilled and unskilled basketball players with their right hand.

# II. Materials and Methods

## 1. Participants

The subjects of this study were 6 high school basketball players in Chungcheongbuk-do and 6 ordinary students who have a set shooting ability near average through regular basketball classes. They are all right-handed <Table 1>.

**<Table 1>** Subjects' general characteristics

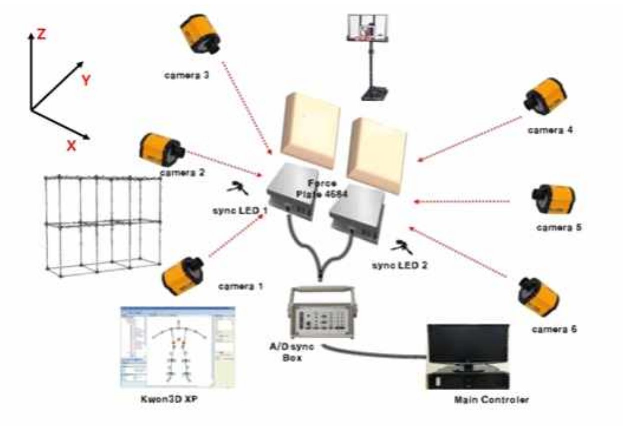
| | Subjects | Age | Height (cm) | Weight (kg) | Career (Year) |
|---|---|---|---|---|---|
| Skilled | S1 | 18 | 177 | 76 | 8 |
| | S2 | 18 | 175 | 75 | 7 |
| | S3 | 18 | 179 | 77 | 7 |
| | S4 | 18 | 180 | 79 | 6 |
| | S5 | 18 | 181 | 78 | 5 |
| | S6 | 18 | 174 | 69 | 5 |
| Average | | 18 | 177.6 | 75.6 | 6.3 |
| Unskilled | S7 | 18 | 175 | 75 | |
| | S8 | 18 | 174 | 74 | |
| | S9 | 18 | 176 | 75 | |
| | S10 | 18 | 176 | 81 | |
| | S11 | 18 | 173 | 78 | |
| | S12 | 18 | 182 | 74 | |
| Average | | 18 | 176 | 76.1 | |

## 2. Procedure

This study was conducted at K University Gymnasium, Chungcheongbuk-do, Korea.

The reference point of the spatial coordinates was set in the direction of conducting the set shot, which is the front of the study subject, and the left and right directions of the human body were set to the X-axis, the front and rear directions to the Y-axis, and the vertical direction to the ground was set to the Z-axis.

The cameras were set in six locations where marker observation is the easiest throughout the set-shooting process. After checking the level of the gym floor with the level, the ground reaction machine was installed 5cm apart. 36 control points were regularly arranged on a 2m × 2m × 1m control point bar, and the control point bar was photographed for 5 seconds and then removed. Two synchronization timers (LED) were installed within the camera's video range for camera-to-camera and camera-to-ground reaction machines, and the camera shooting speed was set to 100 frames/sec. The layout of the experiment equipment is in [Figure 2]. After the placement of experiment equipment, the subject with the marker attached to the joint point climbed on the ground reaction machine to measure the weight, measured the static trial once for 1 second in the anatomical position, and then performed the dynamic trial. Each athlete and general student were measured 6 times. The subject performed a set shot in the preset direction. After completing the first set of shots, the subjects withdrew from the ground reaction machine and allowed to rest for about one minute before taking the second set of shots. 6 shots were performed in the same manner. The distance to the basketball goal for the set shot was set to 4.2 m, the free-throw distance. All subjects were right-handed and shot.




**[Figure 2]** Experimental placement (Nam, 2018)

## 3. 3D coordinate calculation

Kwon 3D 3.1 program was used to coordinate the control point of the reference scale and the center of the body joint. The display of certain intervals was converted into coordinates by digitizing, and the joints and joint centers of the body were displayed by a certain number of coordinates. Then we coordinated the following scene. In this study, Body Segment Parameters used data from Tylkosky (1982). The 3D coordinates of this study are calculated using Abdel-Aziz and Karara (1971) 's Direct Linear Transformation method. When calculating the 3D coordinate values, noise is generated by various causes and smoothing is performed to remove such noise. In this study, the low pass filter method (Walton, 1981) smoothed the data to 6 Hz to calculate 3D coordinate values.

## 4. Measurement event

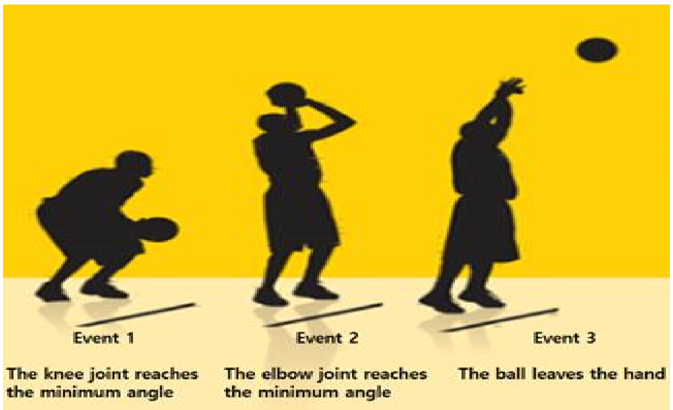
To analyze set shot movement, this study set up the following events.

Event setting [Figure 3]

① Event 1: The knee joint reaches the minimum angle

② Event 2: The elbow joint reaches the minimum angle

③ Event 3: The ball leaves the hand




**[Figure 3]** Events

## 5. Data Processing

In this study, the SPSS program was used to calculate the mean and standard deviation of the kinematic variables in the measurement intervals for the skilled and unskilled subjects. T-test was used to determine the difference.

# III. Results

**<Table 2>** Angle (deg)

| Subjects \ Event | | E1 | E2 | E3 |
|---|---|---|---|---|
| Elbow | Skilled (n=6) | 61.4±6.7 | 58.6±5.9 | 138.3±9.0 |
| | Unskilled (n=6) | 60.7±3.1 | 56.6±2.3 | 136.9±3.1 |
| | t-value | 0.21 | 0.77 | 0.37 |
| Shoulder | Skilled (n=6) | 97.4±3.6 | 92.4±5.7 | 116.3±7.0 |
| | Unskilled (n=6) | 76.4±12.2 | 72.6±12.4 | 113.2±8.8 |
| | t-value | 4.03* | 3.54* | 0.67 |
| Hip | Skilled (n=6) | 150.6±10.1 | 157.7±6.9 | 168.7±3.4 |
| | Unskilled (n=6) | 115.2±12.7 | 161.1±10.2 | 169.8±4.6 |
| | t-value | 5.31* | -0.66 | -0.47 |
| Knee | Skilled (n=6) | 91.6±18.5 | 100.6±13.8 | 149.7±9.6 |
| | Unskilled (n=6) | 106.3±21.6 | 121.8±15.9 | 160.2±11.5 |
| | t-value | -1.26 | -2.46* | -1.69 |

*p<.05
E1: The knee joint reaches the minimum angle
E2: The elbow joint reaches the minimum angle
E3: The ball leaves the hand

## 1. Angle

1) Elbow Joint Angle

As shown in Table 2, the mean and standard deviation of the right elbow joint angle during set shot movements of unskilled subjects were 60.7 ± 3.1 deg at E1, 56.6 ± 2.3 deg at E2, and 136.9 ± 3.1 deg at the E3. The mean and standard deviation of the right elbow joint angle during set shot movements of skilled subjects were 61.03 ± 6.70 deg at E1, 58.57 ± 6.95 deg at E2, and 138.25 ± 10.66 deg at E3.

Satem, Messier, and McNulty (1989) found that competent shooters shoot at greater elbow joint flexion than beginners. Also, Lee (1999) reported that the flexion of the elbow joint is a preparatory action for the successful shooting operation, controlling the shooting timing and forming the ball's trajectory as a parabola. Cooper, Adrian & Glassow (1982) also reported that the change in elbow joint angle determines the amount of rotation and throw angle of the ball. To make a successful shot, the elbow joint should be used to improve the torque on the ball. It is important to bend the elbow joint, adjust the preparation and timing for the shot, and adjust the projection angle of the ball for a successful shot. The shooter should prepare for a successful shoot by flexing the elbow from the beginning of the shot, not the final section of the shot. According to Park (2001), the elbow angle of the unskilled person showed a greater elbow angle than the skilled person in the first section of the shooting motion. As such, the researcher predicted that the angle of the elbow of the skilled subject would be smaller than that of the unskilled subject when preparing the shot. However, there was no statistically significant difference.

2) Shoulder Joint Angle

As shown in Table 2, the mean and standard deviation of the right shoulder joint angle of the unskilled subjects was 76.4 ± 12.2 deg at E1, 72.6 ± 12.4 deg at E2, and 113.2 ± 8.8 deg at E3. The mean and standard deviation of the right shoulder joint angle of the skilled subjects were 97.4 ± 3.6 deg at E1, 92.4 ± 5.7 deg at E2, and 116.3 ± 7.0 deg at E3. There was a statistically significant difference in E1 and E2, but not in E3.

The skilled subjects had a larger joint angle on the right shoulder than the unskilled subjects when the knee joint was at the minimum angle and the elbow joint was at the minimum angle. There was a statistical difference.

We predict that the skilled subjects showed a lager angle at E1 and E2 because they stably put the ball on his head and shoots it. On the other hand, the unskilled person is focused on throwing the shot, so it is thought that the ball is placed in front of the body with a small shoulder angle.

According to Park (2004), the shoulder joint showed a smaller angle than the unskilled person. This is also because of the posture holding the ball in the chest.

Wikes (1982) said that the ideal release section of the basketball shot motion requires the shoulder and elbow joints to move upward, while the forearm and wrist move forward as a follow-through movement. Also, the angle of the elbow joint and shoulder joint is a factor that determines the vertical velocity and the projection angle when the basketball is projected. Satem, Messier, and McNulty (1989) suggest that the angle of the shoulder determines the speed factor in the vertical direction and the throw angle of the basketball. Such flexion of the shoulder joint is an important factor in projecting the basketball, like the flexion of the elbow joint. Bae (2011) reported that the angle of the right shoulder joint was 76.20 ° for the skilled, 94.22 ° for the unskilled, and the angle of the left shoulder joint was 90.52 ° for the skilled and 95.24 ° for the unskilled.

In the basketball set-shooting movement, the shoulder joint angle of the skilled was smaller than the unskilled person due to the flexion when the knee joint was the minimum angle and the elbow joint was the minimum angle.

Therefore, the unskilled person should attach the ball toward the body and make the shoulder angle smaller when the ball leaves the hand for projection angle and projection velocity when preparing a shot.

3) Hip Joint Angle

As shown in Table 2, the mean and standard deviation of the hip angle of the unskilled subject set shot were 115.2 ± 12.7 deg at E1, 161.1 ± 10.2 deg at E2, and 169.8 ± 4.6 deg at E3. The mean and standard deviations of the hip angle of the skilled subject set shot were 150.6 ± 10.1 deg at E1, 157.7 ± 6.9 deg at E2, and 168.7 ± 3.4 deg at E3. There was a statistically significant difference in E1.

Skilled subjects had a smaller hip joint angle than unskilled when the knee joint was at a minimum angle, and there was a statistical difference.

The angle of the hip joint of the skilled, which indicates the angle of the upper body and lower body, was greater than that of the unskilled. It seems that the upper body is not bent, and the lower body is bent instead to maintain stability. The reason why a skilled do not bend their upper body is because they have good wrist strength and can exert enough distance or rotational force. In many sports, the lower body is bent to maintain stability rather than bending the upper body. The reason for the difference between the lower body angle and torso angle is the ability to exert force in two ways (Cruz et al., 2013). The unskilled bowed the upper body more because they want to prepare for the shot and throw with greater power. Also, in skilled subjects, elbow joint, shoulder joint, and hip joint showed a similar angle at E1 and E2. This is thought to be aimed at increasing the success rate of the shot by simplifying the motion and maintaining a stable posture. According to Seo (2010), hip joint angles during the release section were reported to be greater than those of the unskilled.

In the basketball set-shooting movement, the angle of the skilled was larger than the unskilled person due to the stretch of the hip joint when the knee joint was the minimum angle.

Therefore, an unskilled person should lower the lower body instead of bowing the upper body when preparing for a shot and make the posture stable by stretching the hip joint angle.

4) Knee Joint Angle

As shown in Table 2, the mean and standard deviation of the knee joint angle of unskilled set shots were 106.3 ± 21.6 deg at E1, 121.8 ± 15.9 deg at E2, and 160.2 ± 11.5 deg at E3. The mean and standard deviations of the knee joint angle of the skilled set shots were 91.6 ± 18.5 deg at E1, 100.6 ± 13.8 deg at E2, and 149.7 ± 9.6 deg at E3. There was a statistically significant difference in E2.

Skilled subjects had a smaller knee joint angle than unskilled when the knee joint was at a minimum angle, and there was a statistical difference.

Unskilled people stretched to greater angles in the course of E1 to E2. The knee is extended more, which can be interpreted as trying to gain ground reaction force for the shot. However, the unskilled person showed significantly different angles in all three sections, which would not lead to a stable shooting. On the other hand, the skilled person maintained nearly the same angles for all three joints, even the angle of the knee, at E1 and E2, leading to a stable shot connection. In the knee bending movement, when the knee is abruptly used, the moment of the knee increases, and the tibial movement to the anterior increases markedly and the load on the anterior cruciate ligament becomes several times greater (Fukuda, Woo & Loh, 2003). According to Bae (2011), the angles of knee joints and ankle joints were greater in the final shot than in the unskilled person, but in this study, there was no difference when the ball leaves the hand.

In basketball set-shooting movements, the angle of the knee joint appeared smaller when the elbow was at a minimum angle compared to the unskilled.

Therefore, an unskilled person should not straighten his knees to get the strength to throw a shot just before it is thrown, maintain the knee angle for a stable posture, and make the knee angle smaller when the elbow is at a minimum angle.

## 2. Angular velocity

1) Elbow Joint Angular Velocity

The extension of each joint was marked with (+) and the flexion was marked with (-).

As shown in Table 3, the mean and standard deviation for the angular velocity of the elbow joint in the set shot of the unskilled was 27.8 ± 19.3 deg/s in E1, 37.8 ± 19.5 deg/s in E2, and 245.0 ± 11.5 deg/s in E3. Besides, the mean and standard deviation for the angular velocity of the elbow joint in the set shot of the skilled was 35.9 ± 26.9 deg/s in E1, 68.9 ± 19.7 deg/s in E2, and 255.4 ± 10.3 deg/s in E3. There was a statistically significant difference in E2.

**<Table 3>** Angular velocity (deg / s)

| Subjects | Event | E1 | E2 | E3 |
|---|---|---|---|---|
| Elbow | Skilled (n=6) | 35.9±26.9 | 68.9±19.7 | 255.4±10.3 |
| | Unskilled (n=6) | 27.8±19.3 | 37.8±19.5 | 245.0±11.5 |
| | t-value | 0.59 | 2.73* | 1.63 |

| | | | | |
|---|---|---|---|---|
| Shoulder | Skilled (n=6) | 25.4±9.4 | 64.5±16.3 | 322.1±18.7 |
| | Unskilled (n=6) | 41.4±37.3 | 37.2±16.1 | 371.4±41.1 |
| | t-value | -1.01 | 2.91* | -2.66* |
| Hip | Skilled (n=6) | 30.8±9.1 | 103.7±29.3 | -71.0±71.8 |
| | Unskilled (n=6) | 2.9±21.2 | 54.7±72.1 | -18.3±36.8 |
| | t-value | 2.94* | 1.54 | -1.59 |
| Knee | Skilled (n=6) | -0.7±2.0 | 153.4±55.9 | 279.1±18.4 |
| | Unskilled (n=6) | -0.4±2.1 | 167.8±41.2 | 172.0±74.7 |
| | t-value | -0.19 | -0.50 | 3.40* |

*p<.05
E1: The knee joint reaches the minimum angle
E2: The elbow joint reaches the minimum angle
E3: The ball leaves the hand

Skilled individuals had a greater angular velocity of elbow joint than unskilled when the elbow joint was at a minimum angle and there was a statistical difference.

Since the angles of E1 and E2 were constant in the analysis, the angular speed should be raised to some extent when the ball is shot. The skilled subjects choose to use force efficiently. And since such forces must be adjusted for the accuracy of the shot, the size of the force does not need to be large. On the other hand, unskilled people had similar angular speeds at E1 and E2 but quickly accelerated at the last minute. This raises questions about the efficiency of the power to throw the ball, but the accuracy of the shot is also questionable. In the last section, the angular velocity of the skilled and the unskilled was similar and there was no difference.

Choi (1992) said that the difference between two and three-run shots is from the difference in speed between the forearm and the hand division. Lee, Hong, & Yun (2012) found no difference in forearm speed depending on the distance of the 3-pointer. This proves that the speed of the forearm varies according to proficiency and also that the angular velocity varies depending on the distance, but there is no difference for a slight difference in distances. And the link between the elbow extension and the elbow and wrist coordination is as important as the wrist snap when throwing shots (Button, Macleod, Sanders, & Coleman, 2003; Mullineux & Uhl, 2010; Stuart & Roger, 1996). And the increased activity of the upper triceps in the elbow joint is thought to be an attempt to increase the projection distance by increasing elbow angular velocity and joint operating range (Miller & Bartlett, 1993).

In the basketball set shoot motion, the angular velocity of the elbow joint of the skilled subjects appeared to be greater when the elbow was at a minimum angle compared to the unskilled.

Thus, the unskilled must increase the speed of the forearm just before the shot is thrown and the angular velocity of the elbow should be increased when the elbow is at a minimum angle.

2) Shoulder Joint Angular Velocity

As shown in Table 3, the mean and standard deviation for the angular velocity of the shoulder joint of the unskilled were 41.4 ± 37.3 deg/s in E1, 37.2 ± 16.1 deg/s in E2, and 371.4 ± 41.1 deg/s in E3. The mean and standard deviation for the shoulder joint angular velocity during the skilled subjects' set shots were 25.4 ± 9.4 deg/s in E1, 64.5 ± 16.3 deg/s in E2, and 322.1 ± 18.7 deg/s in E3. There were statistically significant differences in E2 and E3.

Skilled people had a greater angular velocity of shoulder joint than unskilled when elbow joint was at a minimum angle, and the angular velocity of the shoulder joint was smaller than unskilled when the ball left the hand.

While skilled subjects' shoulder angular velocity increased, unskilled E1 and E2 showed nearly the same figures and increased sharply at the end. This is the posture of raising the shoulder and raising the ball. The figures show that skilled people naturally raised their shoulders with increasing angular velocity, while unskilled players raised their shoulders sharply after putting the ball up to their heads. The angular velocity of an unskilled man appeared to be greater at the last minute, and it appears that a less experienced unskilled subject, compared to a skilled subject who has thrown many shots, has taken greater effort to throw the ball to the target.

Wikes (1982) said that when releasing a basketball, the right shoulder joint moves upward and forearm & wrist move forward, and this perfect forward snap action of the wrist results in greater follow-through motion. The angular velocity of the hand reported by Holt and Yates (1983) is a factor that determines the amount of rotation and the projection angle of the basketball, and that the rotation force of the basketball should be greater for successful shooting, and that the overall arm's angular speed should be greater.

In the basketball set shoot, the angular velocity of the shoulder joint was greater than that of the unskilled when the elbow joint had a minimum angle and the angular velocity of the shoulder joint was smaller than that of the unskilled when the ball left the hand.

Therefore, the unskilled should naturally increase the angular velocity, rather than making it abrupt only at the last minute during the set-shooting section. Use snap and follow through to rotate the ball, increasing the angular velocity of the entire arm, and increasing the angular velocity of the shoulder when the elbow joint is at a minimum angle.

3) Hip Angular Velocity

As shown in Table 3, the mean and standard deviation for the angular velocity of the hip joint of the unskilled were 2.9 ± 21.2 deg/s in E1, 54.7 ± 72.1 deg/s in E2, and -18.3 ± 36.8 deg/s in E3. The mean and standard deviation for the shoulder joint angular velocity during the skilled subjects' set shots were 30.8 ± 9.1 deg/s in E1, 103.7 ± 29.3 deg/s in E2, and -71.0 ± 71.8 deg/s in E3. There were statistically significant differences in E2 and E3.

The skilled person seems to have tried to raise the upper body in preparation for throwing the ball. The flexion in the last section is observed in both the skilled and the unskilled as a reaction force of the ball throwing force. The unskilled person had lower bends and all the values were smaller than the skilled ones, but the difference was at E1. Park (2004) reported that the femoral synthesis rate was faster for the unskilled and that the unskilled had a higher dependence on shooting using the force of the lower limbs. If the lower body is fixed, the upper body movement will indicate the angular velocity of the hip, but the lower body and femoral force may affect the angular velocity of the hip. Female athletes rely more on quadriceps to stabilize their knees (Malinzak et al., 2001). The connection between the upper body and the knee is the thigh and hip joints. Thus, they do not only play the role of the mediator between the upper and lower body but affects the knees.

In the basketball set shoot, the angular velocity of the hip joint was greater than that of the unskilled when the knee joint was at a minimum angle.

Therefore, unskilled people should use the lower body strength during the set shot to increase the angular velocity, and bend more as a reaction at the last moment when the ball leaves the hand. And when the knee joint is at its minimum angle, the angular velocity of the hip joint should be increased.

4) Knee Joint Angular Velocity

As shown in Table 3, the mean and standard deviation for the angular velocity of the hip joint of the unskilled were −0.4 ± 2.1 deg/s in E1, 167.8 ± 41.2 deg/s in E2, and 172.0 ± 74.7 deg/s in E3. The mean and standard deviation for the shoulder joint angular velocity during the skilled subjects' set shots were −0.7 ± 2.0 deg/s in E1, 153.4 ± 55.9 deg/s in E2, and 279.1 ± 18.4 deg/s in E3. There were statistically significant differences in E2 and E3.

At E1 and E2, skilled and unskilled people show almost the same figures. At E3, however, skilled people represent almost twice the angular velocity, but unskilled people present a figure similar to that of E2. In the unskilled group, they used high arm angular velocities while little leg angular velocity. Seo (2010) reported that the angular velocity of the knee joint in the maximum flex event and release event of the skilled subjects were statistically significantly greater than that of the unskilled. In the process of bent and stretch of the knee, a great load is placed on the knee when the activity of the quadriceps and extra torque is combined (Arms, Pope, Johnson, Fischer, Arvidsson, & Eriksson, 1984). The load is applied even when it is stretched and bent. In particular, female athletes bend their knees less after reaction landing. This puts more load on the anterior cruciate ligament of female athletes (Ford, Myer, & Hewett, 2003). In basketball shooting, there are times when the angular velocity is increased to use greater force, not only for a distant set shot but also for a jump or landing of such a jump. Beginners should also pay attention to the prevention of such injuries.

In the basketball set shoot, the angular velocity of the knee joint was greater than that of the unskilled when the ball left.

Therefore, one should focus on increasing the angular velocity of the legs and knees rather than increasing the angular velocity of the arms. And when the ball leaves, the angular velocity of the knee joint must be increased.

## 3. Ground Reaction Force

1) Fx

As shown in Table 4, the mean and standard deviation for the right foot lateral ground reaction forces in unskilled subjects' set shot were −50.2 ± 54.9 N/BW in E1 and −65.6 ± 68.6 N/BW in E2, and −11.0 ± 10.9 N/BW in E3. The mean and standard deviation for the right foot lateral ground reaction forces in skilled subjects' set shots were 50.5 ± 15.6 N/BW in E1, 65.3 ± 20.3 N/BW in E2, and 1.4 ± 4.5 N/BW in E3.

The mean and standard deviation for the left foot lateral ground reaction forces in the unskilled subjects' set shots were 72.4 ± 33.1 N/BW in E1, with 100.5 ± 39.6 N/BW in E2, and 9.8 ± 6.8 N/BW in E3. The mean and standard deviations of lateral ground reactions in the left foot of the skilled subjects' set shot were 50.7 ± 15.4 N/BW at E1, 65.3 ± 20.4 N/BW at E2 and 1.51 ± 4.5 N/BW at E3.

**<Table 4>** Ground reaction force (N / BW)

| Subjects \ Event | | | E1 | E2 | E3 |
|---|---|---|---|---|---|
| Fx | Skilled (n=6) | Right | 50.5±15.6 | 65.3±20.3 | 1.4±4.5 |
| | | Left | 50.7±15.4 | 65.3±20.4 | 1.51±4.5 |
| | Unskilled (n=6) | Right | -50.2±54.9 | -65.6±68.6 | -11.0±10.9 |
| | | Left | 72.4±33.1 | 100.5±39.6 | 9.8±6.8 |

| | | | | | |
|---|---|---|---|---|---|
| | t-value | Right | 4.32* | 4.48* | 2.58* |
| | | Left | -1.44 | -1.93 | -2.47* |
| Fy | Skilled (n=6) | Right | -19.7±6.8 | 0.4±20.1 | 3.0±9.6 |
| | | Left | -34.1±8.0 | -42.1±7.5 | 26.7±6.3 |
| | Unskilled (n=6) | Right | -5.9±10.1 | 7.7±12.1 | -6.7±6.6 |
| | | Left | -16.2±20.5 | -28.1±11.7 | 18.3±13.1 |
| | t-value | Right | -2.76* | -0.76 | 2.05 |
| | | Left | -1.98 | -2.44* | 1.40 |
| Fz | Skilled (n=6) | Right | 543.3±15.2 | 630.7±26.7 | 150.4±71.4 |
| | | Left | 539.1±18.8 | 608.2±15.7 | 154.8±52.0 |
| | Unskilled (n=6) | Right | 451.0±54.7 | 514.8±65.9 | 130.3±44.0 |
| | | Left | 465.9±51.0 | 550.0±51.3 | 151.3±67.5 |
| | t-value | Right | 3.98* | 3.99* | 0.58 |
| | | Left | 3.29* | 2.65* | 0.09 |

*p<.05

E1: The knee joint reaches the minimum angle

E2: The elbow joint reaches the minimum angle

E3: The ball leaves the hand

2) Fy

In the unskilled subjects' set shot, the mean and standard deviation for the longitudinal ground reaction force on the right foot was −5.9 ± 10.1 N/BW in E1, 7.7 ± 12.1 N/BW in E2, and - 6.7 ± 6.6 N/BW in E3. In the skilled subjects' set shot, the mean and standard deviation for the longitudinal ground reaction force on the right foot was −19.7 ± 6.8 N/BW in E1, 0.4 ± 20.1 N/BW in E2, and 3.0 ± 9.6 N/BW in E3.

In the unskilled subjects' set shot, the mean and standard deviation for the longitudinal ground reaction force on the left foot was −16.2 ± 20.5 N/BW at E1, −28.1 ± 11.7 N/BW at E2, and 18.3 ± 13.1 N/BW at E3. In the skilled subjects' set shot, the mean and standard deviation for the longitudinal ground reaction force on the left foot was −34.1 ± 8.0 N/BW in E1, −42.1 ± 7.5 N/BW in E2, and 26.7 ± 6.3 N/BW in E3.

3) Fz

In the unskilled subjects' set shot, the mean and standard deviation for right foot vertical ground reaction force was shown at 451.0 ± 54.7 N/BW in E1, 514.8 ± 65.9 N/BW in E2, and 130.3 ± 44.0 N/BW in E3. In the skilled subjects' set shot, the mean and standard deviation for the vertical ground reaction force on the right foot was 543.3 ± 15.2 N/BW in E1, 630.7 ± 26.7 N/BW in E2, and 150.4 ± 71.4 N/BW in E3.

In the unskilled subjects' set shot, the mean and standard deviation for the vertical ground reaction force on the left foot was 465.9 ± 51.0 N/BW at E1, 550.0 ± 51.3 N/BW at E2, and 151.3 ± 67.5 N/BW at E3. The mean and standard deviations of vertical ground reactions in the left foot of the skilled subjects' set shot were 539.1 ± 18.8 N/BW at E1, 608.2 ± 15.7 N/BW at E2, and 154.8 ± 52.0 N/BW at E3.

The lateral forces of the left and right feet were exerted by the outer right feet as compared to the unskilled when of E1 and E2. At this moment the unskilled was forced into the inner direction, the opposite direction of the skilled. At the last moment, the skilled maintained a neutral direction, and the unskilled continued to have a force in their right foot. The skilled maintained the center of the force to the last moment, and the unskilled at all three points exerted the force to the inner side of the right foot.

The longitudinal ground reaction forces were applied at E1 point on the right foot from both of skilled and unskilled. It is believed that the skilled player played a bigger role and that the ready position before the shot was pulled back with stable weight. On the left foot, both skilled and unskilled at E2 applied a backward force. This can be seen as the result of the weight being pulled back while the ball is raised above the head and the left foot was placed at the back of the right foot. Conversely, at this time, the right foot did not force backward.

The vertical ground reaction forces were applied more to the skilled on the right foot. Both E1 and E2 showed a higher value for the skilled. There was no difference at the last point. Similarly, in the left foot, a greater force was applied vertically than in the unskilled, and there was no difference at the last point. Both the right and left feet showed similar levels, with both the right and the left feet having a greater force than the unskilled.

Gu et al (2009) reported that in the ground reaction force study of the free-throw motion of basketball, the skilled person at the time of release showed greater values in both lateral and longitudinal directions than unskilled but smaller in vertical directions. This study did not differ at the time of release. It was also found to be related to the size of the ground reaction when shooting basketball (Hewett, Paterno, Myer, 2002) and the injury of the musculoskeletal system, as the weight of the ground is applied to the front of the foot while bending the knee (Arend & Dick, 1995). Kim and Eun (2009) analyzed the maximum vertical ground reaction force for adult males and reported that the maximum ground reaction force was an average of 1,624 N (2.24 BW) and an average of 1,612 N (2.22 BW) when in control, but this study divided exerted Newton (N) by body weight (BW). Cornwall & McPoil (2000) said that the pressure center is where the sum of moments caused by vertical forces is zero and is the same meaning as the position of the point of application. In this study, the lateral ground reaction force on the right feet of skilled subjects was applied outwardly, and at the moment they shot, they kept neutral to focus on the vertical force. Right-handed players seem to be working inwardly because they usually hang stops with their right foot when trying to shoot, and because their left foot has to contribute to jumping, that is, to the top.

Compared to unskilled players in basketball set shoot movements,

the lateral ground reaction forces were applied on the right foot to the outside at every moment, and on the left foot, the force was applied from the inside when the ball left the hand.

The longitudinal ground reaction force acted backward when the knee joint was at the minimum angle on the right foot and acted backward when the elbow joint was at the minimum angle on the left foot.

The vertical ground reaction force acted upward on the right and left foot when the knee joint was at the minimum angle and the elbow joint was at the minimum angle.

Therefore, an unskilled person must exert force on the right foot outward, backward, and upward, and on the left foot upward when the elbow is at its minimum angle. When the elbow joint is at its minimum angle, exert force on the right foot outward and upwards, and on the left foot backward and upward. Finally, when the ball leaves the hand, both the right and left foot must exert force to outward direction. The summary of the skilled results is as follows(Table 5).

**<Table 5>** Skilled results summary

| Variable \ Event | | E1 | E2 | E3 |
|---|---|---|---|---|
| Elbow | Angle | - | - | - |
| | Angular Velocity | - | Large | - |

| | | | | | |
|---|---|---|---|---|---|
| Shoulder | Angle | | Large | Large | - |
| | Angular Velocity | | - | Large | Small |
| Hip | Angle | | Large | - | - |
| | Angular Velocity | | Large | - | - |
| Knee | Angle | | - | Small | - |
| | Angular Velocity | | - | - | Large |
| Ground Reaction Force | Fx | Right | Large | Large | Large |
| | | Left | - | - | Small |
| | Fy | Right | Small | - | - |
| | | Left | - | Small | - |
| | Fz | Right | Large | Large | - |
| | | Left | Large | Large | - |

E1: The knee joint reaches the minimum angle
E2: The elbow joint reaches the minimum angle
E3: The ball leaves the hand

# IV. Conclusions

This study kinetically analyzes and describes a basketball set shot movement to understand the mechanism. The study intends to provide source data for teachers and students who want to analyze basketball set shot movement scientifically. To achieve the purpose of this study, a total of 12 subjects, including 6 skilled and 6 unskilled basketball players participated. The basketball set shot movement, from knee joint reaching its minimum angle to the ball leaving the hand, was analyzed. Mean kinetic variables related to the movement including angle, angular velocity, and ground reaction force were verified. The results are as follows:

First, the shoulder joint angle of the skilled was smaller than the unskilled person due to the flexion when the knee joint was the minimum angle and the elbow joint was the minimum angle. Therefore, the unskilled person should attach the ball toward the body and make the shoulder angle smaller when the ball leaves the hand for projection angle and projection velocity when preparing a shot. The hip joint angle of the skilled was larger than the unskilled person due to the stretch of the hip joint when the knee joint was the minimum angle. Therefore, an unskilled person should lower the lower body instead of bowing the upper body when preparing for a shot and make the posture stable by stretching the hip joint angle. The angle of the knee joint of the skilled subjects appeared smaller when the elbow was at a minimum angle compared to the unskilled. Therefore, an unskilled person should not straighten his knees to get the strength to throw a shot just before it is thrown, maintain the knee angle for a stable posture, and make the knee angle smaller when the elbow is at a minimum angle.

Second, the angular velocity of the elbow joint of the skilled subjects appeared to be greater when the elbow was at a minimum angle compared to the unskilled. Thus, the unskilled must increase the speed of the forearm just before the shot is thrown and the angular velocity of the elbow should be increased when the elbow is at a minimum angle. The angular velocity of the shoulder joint was greater than that of the unskilled when the elbow joint had a minimum angle and the angular velocity of the shoulder joint was smaller than that of the unskilled when the ball left the hand. Therefore, the unskilled should naturally increase the angular velocity, rather than making it abrupt only at the last minute during the set-shooting section. Use snap and follow through to rotate the ball, increasing the angular velocity of the entire arm, and increasing the angular velocity of the shoulder when the elbow joint is at a minimum angle. The angular velocity of the hip joint was greater than that of the unskilled when the knee joint was at a minimum angle. Therefore, unskilled people should use the lower body strength during the set shot to increase the angular velocity, and bend more as a reaction at the last moment when the ball leaves the hand. And when the knee joint is at its minimum angle, the angular velocity of the hip joint should be increased. The angular velocity of the knee joint was greater than that of the unskilled when the ball left. Therefore, one should focus on increasing the angular velocity of the legs and knees rather than increasing the angular velocity of the arms. And when the ball leaves, the angular velocity of the knee joint must be increased.

Third, the lateral ground reaction force acted outward the whole time on the right foot, and inward when the ball left the hand on the left foot. The longitudinal ground reaction force acted backward when the knee joint was at the minimum angle on the right foot and acted backward when the elbow joint was at the minimum angle on the left foot. The vertical ground reaction force acted upward on the right and left foot when the knee joint was at the minimum angle and the elbow joint was at the minimum angle. Therefore, an unskilled person must exert force on the right foot outward, backward, and upward, and on the left foot upward when the elbow is at its minimum angle. When the elbow joint is at its minimum angle, exert force on the right foot outward and upwards, and on the left foot backward and upward. Finally, when the ball leaves the hand, both the right and left foot must exert force to outward direction.

## References


Adbel-Aziz, Y. I. (1971). Direct linear transformation from comparator coordinates into object space coordinates in close-range photogrammetry. Proceeding ASP UI Symposium on Close-Range photogrammetry, Falls Church, VA: American Society of Photogrammetry.

Arendt, E., & Dick, R. (1995). Knee injury patterns among men and women in collegiate basketball and soccer: NCAA data and review of literature. *American Journal of Sports Medicine, 23*, 694-701.

Arms, S. W., Pope, M. H., Johnson, R. J., Fischer, R. A., Arvidsson, I., & Eriksson, E. (1984). The biomechanics of anterior cruciate ligament rehabilitation and reconstruction. *American Journal of Sports Medicine, 12*. 8-18.

Bae, J. H. (2011). *A Kinematic Analysis of Body Segmentation in Free Basketball Movement.* Unpublished master's thesis. Chungnam National University, Taejon, The Republic of Korea.

Brancazoi, P. J. (1984). Sports sciences – Physical laws and optimal performance. New York: Simon & Schuster.

Button, C., Macleod, M., Sanders, R., & Coleman, S. (2003). Examining movement variability in the basketball free-throw action at different skill levels. *Research Quarterly for Exercise and Sport, 74*(3), 257-269.

Chae, O. H., & Kwon, H. K. (2016). Development of brain-based learning scale. *Brain, Digital, & Learning, 6*(3), 111-119.

Choi, J. Y. (1992). *The kinematic analysis of basketball jump shot motion according to projectile distance.* Unpublished master's thesis, Yonsei University, Seoul, The Republic of Korea.

Cooper, J, M., Adrian, M J., & Glassow, R. B. (1982). Kinesiology. Saint Louis: Bosby.

Cooper, J. M., & Siedentop, D. (1975). The theory and science of basketball(2nd ed). Philadelphia: Lee and Febiger.

Cornwall, M. W., & McPoil, T. G. (2000). Velocity of the center of pressure during walking. *Journal of the American Podiatric Medical Association, 89*(6), 278-291.

Cruz, A., Bell, D., McGrath, M., Blackburn, T., Padua, D., & Herman, D. (2013). The effects of three jump landing tasks on kinetic and kinematic measures: implications for ACL injury research. *Research in Sports Medicine. 21*(4), 330-342.

Elliotte, B., & Smith, J. (1983). The relationship of selected Biomechanics & anthropometric measure to accuracy in netball shooting. *Journal of Human Movement Studies, 9*(4), 171-187.

Ford, K. R., Myer, G. D., & Hewett, T. E. (2003). Valgus knee motion during landing in high school female and male basketball players. *Medicine & Science in Sports & Exercise, 35*(10), 1745-1750.

Fukuda, Y., Woo, S. L., & Loh, J. C. (2003). A quantitative analysis of valgus torque on the ACL: a human cadaveric study. *Journal of Orthopaedic Research, 21*, 1107-1112.

Goosey-Tolfrey, V., Butterworth, D., & Morriss, C. (2002). Free throw shooting technique of male wheelchair basketball players. *Adapted Physical Activity Quarterly, 19*(2), 238-250.

Gu, H. M., Chae, W. S., Kang, N. J., Yoon, C. J., Jang, J. I. (2009). Comparative Analysis of Muscle Activity and Ground Reaction Force between Skilled and Unskilled Player during a Free Throw. *Korean Journal of Sport Biomechanics, 19*(2), 347-357.

Hayes, D. (1987). Body segment contributions to free throw shooting in basketball. In ISBS-Conference Proceedings Archive.

Hewett, T. E., Paterno, M. V., & Myer G. D. (2002). Strategies for enhancing proprioception and neuromuscular control of the knee. *Clinical Orthopedic, 402*, 76-94.

Holt, L. E., & Yates, G. (1983). The development of multiple linear regression equation to predict accuracy in basketball jump shooting. Biomechanics in Sports. *Research for Center for Sports,* 103-109.

Ju, M. D. (1989). Determination of the optimum release angles and velocities in the basketball free throw and 3-point field shooting. *Korean Journal of Physical Education, 28*(1), 313-320.

Kim, Y. W., Eun, S. D. (2009). The effects of restricted trunk motion on the performance of maximum vertical jump. *Korean Journal of Sport Biomechanics, 19*(1), 27-36.

Kirby, R. F., & Roberts, J. A. (1985). Techniques of basketball. Introductory Biomechanics, Sandy Sharpe of Movement Publication. Inc, 325-346.

Lee, D. J. (1999). Kinematic analysis of the motion of three-point Jump shoot in basketball. Unpublished master's thesis, Chungnam National University, Taejon, The Republic of Korea.

Lee, K. H., Choi, S. K, Lee, G. N., Kang, S. H., Kim, T. H. (2019). Development of reading ability diagnosis indicators using eye tracker. *Brain, Digital, & Learning, 9*(2), 19-28.

Lee, K. I., Hong, W. K., Yun, C. G. (2012). Analysis on kinematic difference depending on distance change in three-point shot motion of basketball. *Journal of Co*aching Development, *14*(3), 168-175.

Lee, S. J., An, M. J., Kim, K. L. (2019). Effects of step box exercise on health related fitness: Bone mineral density and physical self-concept in obese female middle school students. *Brain, Digital, & Learning, 9(4*), 329-339.

Malinzak, R. A., Colby, S. M., Kirkendall, D. T., Yu, B., & Garrett, W. E. (2001). A comparison of knee joint motion patterns between men and women in selected athletic tasks. *Clinical biomechanics, 16*(5), 438-445.

Macauly, E. E. (1970). Anatomy of the jump shot. *Scholastic Coach, 22*(8)

Martin, T. P. (1981). Movement analysis applied to the basketball jump shot-part II. *Physical Educator, 38*(3), 127.

Miller, S. & Bartlett, R. M. (1993). The effects of increased shooting distance in the basketball jump shot. *Journal of Sports Sciences, 11*(4), 285-293.

Moon, J. H. (2017). *Difference in EEG and sports-confidence by feedback types in free throw.*

Unpublished master’s thesis, Chonbuk National University, Jeonju, The Republic of Korea.

Mullineaux, D. R., & Uhl, T. L. (2010). Coordination-variability and kinematics of misses versus swishes of basketball free throws. *Journal of Sports Sciences, 28*(9), 1017-1024.

Nam, S. G. (2018). *The kinematic comparison analysis of free tipping behavior between male high school basketball players and general students.* Unpublished master’s thesis, Korea National University of Education, Cheongju, The Republic of Korea.

Pang, Y. (1995). Analysis of areas and distances where rebound balls fall in basketball shooting. *The Korean Journal of Physical Education, 34*(1), 207-217.

Park, C. H. & Choi, H. A. (1997). A study on the basketball players' sports injuries. *Journal of Physical Education Research, 4*(1), 71-83

Park, H. S. (2004). *A kinematic analysis of free throw motion in basketball.* Unpublished master’s thesis, Chungnam National University, Taejon, The Republic of Korea.

Park, S. Y. (2001). *A kinematic analysis of free throw motion in basketball.* Unpublished master’s thesis, Chonnam National University, Kwangju, The Republic of Korea.

Russell, C. H. (2009). Kinematics and kinetics of a particle. Engineering Mechanics: Dynamics (12th ed.). Prentice Hall. p. 298.

Satem, N. N., Messier, S. T., & Mcnulty, K. (1989). The effect of ball size basketball height the mechanics of the basketball free throw. *Journal of Human Movement Studies, 16*(3), 123-137.

Seo, J. W. (2010). *Comparative analysis of kinematical variables between skilled and unskilled players during a free throw.* Unpublished master’s thesis, Kyungpook National University, Daegu, The Republic of Korea.

Shim (2019). Self-reflection and reality check for the prosperity of Korean sports biomechanics. Korean Society of Sport Biomechanics spring seminar.

Silverberg, L. M., Tran, C. M., & Adams, T. M. (2011). Optimal targets for the bank shot in men's basketball. *Journal of Quantitative Analysis in Sports, 7*(1). doi:10.2202/1559-0410.1299.

Stuart, M., & Roger, B. (1996). The relationship between basketball shooting kinematics distance and playing position. *Journal of Sports Sciences, 14*(3), 243-253.

Toyoshima, S., Hoshikawa, T., & Ikegami, I. (1981). Effects of initial velocity and angle of projection on accuracy in basketball shooting. *Biomechanics VII-B*. 525-530.

Tylkowski, C. M., Simon, S. R., & Mansour, J. M. (1982). Internal rotation gait in spastic cerebral palsy in the hip. In Nelson, J. P.(Ed.), Proceeding of the 10th Open Scientific Meeting of the Hip Society, St. Louis, MS: Mosby.

Walton, J. S. (1981). *Close-range-photogrammetry : A generalized technique for quantifying gross human motion.* Unpublished doctoral dissertation, The Pennsylvania State University.

Wikes, G. (1982). Fundamental of coaching basketball. Um. C. Brown Company Publisher.

Woo, S. J., Kim, K. L., An, M. J., Ko, D. J. (2019). Effects of unicycle exercise on health related fitness and physical self-efficacy in male middle school students. *Brain, Digital, & Learning, 9*(4), 319-327.

Wooden, J. R. (1999). Practical modern basketball. Benjamin-Cummings Publishing Company.

Yun, S. B., Ho, E. S., Kim, K. L. (2019). Effects of group jump rope on working memory and attention in elementary school students. *Brain, Digital, & Learning, 9*(3), 199-212.

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