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Master's Thesis

A Training and Support System for Three-Point Shooting for Basketball Beginners

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Abstract

Basketball has become one of the most popular sports worldwide in recent years. Among all offensive techniques, the three-point shot has gained significant importance. In the NBA, teams attempted over 30 three-point shots per game on average during the 2023-2024 season, making up nearly one-third of all field goal attempts. Despite its popularity, the three-point shot remains a difficult skill. The long shooting distance leads to a lower success rate than other shots. Even elite NBA teams struggle to exceed a 40% success percentage. Mastering this technique is even more challenging for amateur players and beginners due to a lack of proper training, physical conditioning, and expert guidance.

Traditional training methods include online video instructions and camp-style offline instruction. While these methods provide learning opportunities, they have clear limitations. Online instructions often feature professional players whose shooting mechanics and physical attributes differ significantly from those of beginners. Beginners may attempt to mimic these movements without considering their own physical limitations, leading to ineffective results. In-person training programs, such as basketball camps, focus on repetitive drills. These drills may improve technique but can become monotonous, reducing motivation. Many beginners struggle to stay engaged in such training and may abandon practice before making meaningful progress.

To address these challenges, this research proposes a three-point shooting training and support system specifically designed for basketball beginners. The system leverages computer vision technology, particularly YOLOPose, to analyze and visualize shooting motions. Unlike conventional training methods that only examine the side view of a player's movement, this system analyzes both frontal and lateral perspectives. A multi-perspective approach provides a more comprehensive assessment of shooting form and allows for more precise feedback. The system also includes a personalized matching mechanism that pairs beginners with skilled players who share similar physical characteristics and shooting styles. This customized learning experience ensures that beginners follow shooting models suited to their own bodies. To enhance engagement, the system incorporates a reward subsystem, where participants earn points based on their shooting percentage and adherence to optimal form. These points allow access to higher-quality basketball, motivating beginners to continue training.

A controlled experiment was conducted to evaluate the effectiveness of the proposed system. The study involved 30 participants, including 10 skilled players and 20 beginners. The experiment followed the NBA Three-Point Contest format, in which participants attempted shots from five designated positions on the court. The 20 beginners were divided into two groups. The control group received traditional training, in which lateral only feedback was provided. The experimental group received feedback from both frontal and lateral perspectives through the proposed system. The results showed that beginners in the experimental group improved shooting accuracy more than those in the control group. Furthermore, beginners in the experimental group reported higher levels of motivation and engagement, demonstrating the system’s ability to enhance both performance and training experience.

This research highlights the potential of integrating pose estimation technologies into sports education. The system offers visually intuitive feedback, bridging the gap between professional training methods and amateur development. Traditional coaching often fails to address key biomechanical issues. Many beginners struggle with improper elbow positioning, misalignment of the knee, and inefficient shot release. These issues are difficult to detect through side-view

analysis alone. The proposed system overcomes this limitation by incorporating frontal-perspective analysis. This allows for identifying common shooting errors that might otherwise go unnoticed. By correcting these mistakes, the system improves shooting accuracy, optimizes biomechanics, and reduces the risk of injury.

The experimental results emphasize the importance of a multi-perspective approach to basketball training. The frontal perspective revealed critical shooting errors that were not evident from the lateral only. For instance, some beginners positioned the ball too far to one side before releasing their shot. This issue could not have been detected through lateral only analysis. Correcting such mistakes significantly improved shot consistency. The statistical analysis further confirmed that the experimental group improved shooting accuracy significantly more than the control group.

The study also provides insights into gender differences in three-point shooting training. Female participants faced additional challenges due to differences in body strength, which affected their shooting mechanics. To address this, the system introduced a metric for "correct shots" within the restricted area. This allowed for a more equitable assessment of progress. The experimental results showed that female beginners in the experimental group made significant improvements in shot placement compared to the control group.

The reward subsystem proved to be a strong motivator for beginners. Beginners showed enthusiasm for earning points and unlocking access to higher-quality basketballs. This gamified approach increased engagement and encouraged consistent practice. Sustained training is essential for percentage improvement, and the system's ability to maintain user motivation represents a key advantage over conventional training methods.

In conclusion, this research presents an innovative and technology-enhanced approach to learning three-point shooting. By combining pose estimation, personalized feedback, and gamification, the proposed system provides a more effective and engaging learning experience for beginners. The proposed system overcomes these limitations by offering real-time feedback, customized learning, and interactive motivation. As the system continues to evolve, it has the potential to transform basketball training for players at all levels. By making high-quality training accessible and engaging, this system could significantly improve skill development in basketball and other sports.

This study makes several important contributions. First, it introduces a matching subsystem that matches beginners with skilled players based on physical characteristics. This ensures that beginners train from models suited to their own characteristics, increasing the likelihood of successful skill acquisition. Secondly, it improves upon existing motion analysis techniques by incorporating both frontal and lateral perspectives. Traditional lateral-only analysis often fails to detect frontal perspectives, such as improper ball positioning relative to the face. Thirdly, the research integrates gamification through a reward subsystem. This approach makes training more engaging by allowing beginners to earn points and unlock rewards, fostering long-term motivation.

Despite its promising results, this study has some limitations. The sample size was relatively small, which may limit the generalizability of the results. Future work should expand the participant pool to include a more diverse range of skill levels, genders, and playing styles. Additionally, the database of skilled players did not include female skilled players. This may have impacted the effectiveness of the matching subsystem for female beginners. Future work should incorporate female skilled players to improve inclusivity and effectiveness.

Several areas for future work could further enhance the system. Integrating real-time video analysis would allow for more dynamic training. Instead of analyzing keyframes from videos, the system could provide immediate feedback while a player is shooting. This would enable real-time corrections, improving the training process. The system could also be expanded to include other basketball skills, such as dribbling and defensive maneuvers. Analyzing movement patterns in these areas could provide additional training benefits. Finally, long-term training should be conducted to assess the system's impact over extended training periods. Understanding how the system influences skill development over months or years would provide valuable insights into its effectiveness and sustainability.

Keywords: Basketball, three-point shooting, pose estimation, YOLOPose, matching method, reward method, sports education

Contents

Chapter 1 Introduction 1
1.1 Background 1
1.2 Research Objectives and Questions 2
1.3 Structure of the Thesis 3
Chapter 2 Related Works 4
2.1 Prediction of Basketball Free Throw Shooting by OpenPose 4
2.2 Analyzing the biomechanical characteristics of the three-point shooting motion in basketball 5
2.3 Influence of Physical Education Models on Basketball Performance 6
2.4 Sport expertise and shot results in Basketball Anticipation 7
2.5 Summary 9
Chapter 3 Research Design and Methodology 10
3.1 Proposed method 10
3.2 Matching subsystem 11
3.2.1 Database 11
3.2.2 Matching logic 12
3.3 Computational subsystem 13
3.3.1 Visualization through YOLOPose 13
3.3.2 Calculation of joint angles 16
3.4 Reward subsystem 17
3.4.1 Scoring program 17
3.4.2 Reward program 21
Chapter 4 Experimentation 23
4.1 Experiment introduction 23
4.1.1 Experimental Purpose and Methods 23
4.1.2 Research Design 23
4.2 Flow of the Experiment 27
4.3 Experimental results 31
4.4 Questionnaire results 32

4.5 Discussion 37
Chapter 5 Conclusion and Future Works 38
5.1 Conclusion 38
5.2 Future Works 39
Acknowledgement 40
Publications 41
References 42
Appendix 43

List of Figures

Figure 1.1 NBA 2023-2024 Season Team List[1] ... 2
Figure 1.2 Comparison of beginners and skilled players ... 2
Figure 2.1 Human skeletal points by OpenPose[6] ... 4
Figure 2.2 Real-time shooting probability display[7] ... 5
Figure 2.3 Example of the experimental stimuli[11] ... 8
Figure 2.4 Accuracy (mean±*SD*) under each temporal condition per group[11] ... 8
Figure 2.5 The accuracy (the mean ± *SD*) of each shot result per group under all time conditions[11] ... 9
Figure 3.1 The system's workflow ... 10
Figure 3.2 Database of skilled players ... 11
Figure 3.3 Logic of the matching system ... 12
Figure 3.4 Example usage of the matching system ... 13
Figure 3.5 Key points regression of the human body by YOLOPose[12] ... 13
Figure 3.6 Keyframes of the A01 shooting at top arc ... 14
Figure 3.7 Installation of packages ... 14
Figure 3.8 Analyzation of A01-1.png by yolov8x ... 14
Figure 3.9 Skeletal model of A01 ... 15
Figure 3.10 Obtention of the key points ... 15
Figure 3.11 A01's joints key points from 0-16 ... 16
Figure 3.12 Calculation of the vectors ... 16
Figure 3.13 Calculation of the angles ... 17
Figure 3.14 Scoring program for male beginners ... 18
Figure 3.15 Example usage of male beginners ... 19
Figure 3.16 Restricted Area ... 19
Figure 3.17 Scoring program for female beginners ... 20
Figure 3.18 Example usage of female beginners ... 20
Figure 3.19 Reward basketballs ... 21
Figure 3.20 Reward program of the control group ... 22
Figure 3.21 Reward program of the experimental group ... 22
Figure 4.1 Jaist gymnasiums ... 24
Figure 4.2 Dataset of A01 ... 26
Figure 4.3 Result of post-experiment questionnaire for skilled players ... 33
Figure 4.4 Result of post-experiment questionnaire for beginners B01-B10 ... 34
Figure 4.5 Result of post-experiment questionnaire for beginners B11-B20 ... 34
Figure 4.6 Result of post-Experiment Questionnaire of control group ... 35
Figure 4.7 Result of post-Experiment Questionnaire of experimental group ... 35

List of Table

Table 2.1 Kinematic data for three-point shooting[8] 6
Table 3.1 Difference between 1, 1.5 and 2 motion 11
Table 4.1 Physical characteristics of skilled players 25
Table 4.2 Results of the skilled players 25
Table 4.3 Physical characteristics of beginners 27
Table 4.4 Results of the beginners 31
Table 4.5 The improvement of the angle and shooting percentage 31
Table 4.6 Results of Wilcoxon Rank-Sum Test 31
Table 4.7 Results of female beginners correct shots 32
Table 4.8 Average number of correct shots 32
Table 4.9 Average and standard deviation of skilled players (n=9) 33
Table 4.10 Average and standard deviation of control group's beginners (n=10) 36
Table 4.11 Average and standard deviation of experimental group's beginners (n=10) 36
Table 4.12 Results of Wilcoxon Rank-Sum Test for two groups' beginners 36

Chapter 1 Introduction

1.1 Background

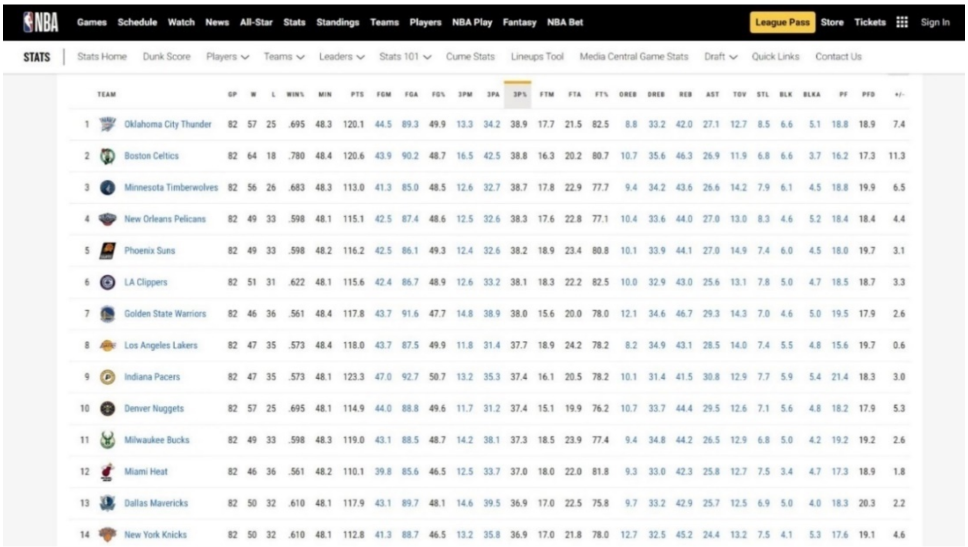
With the development of basketball, it has become a popular sport around the world, attracting many fans to watch basketball games. Among the basketball leagues around the world, the National Basketball Association (NBA), as the highest level and most popular league, has a significant influence on basketball.

Compared to the last century, the NBA's style of play in recent years has emphasized offense and increased the proportion of three-point shots. According to the statistics in figure 1[1], in the 2023-2024 NBA season, each NBA team will shoot over 30 three-point shots per game, accounting for one-third of all shots taken. As a result, many players have emerged as three-point shooters in recent years, and their style of play has been studied by many amateur basketball beginners.

However, because of the distance from the basket, three-point shooting is difficult and has a lower field goal percentage than other shooting styles. In the 2023-2024 NBA season, even the Oklahoma City Thunder, the best three-point shooting team in the NBA, field goal percentage is also less than 40 percent. Compared with NBA players, amateur basketball beginners have less training and guidance, so it is difficult for them to learn three-point shooting. Therefore, learning three-point shooting to improve their field goal percentage is a difficult problem for beginners to solve.

Traditional basketball instruction comes in two forms: online video instruction and camp-style offline instruction. In the online instructional videos, the learning targets are often professional players in the NBA or other leagues. Compared with these professional players, beginners have a large difference in height, arm span, muscle mass and other physical characteristics, so learning their shooting motions may not be suitable for the beginners, and the effect of improving the three-point shooting percentage may not be ideal. At the same time, most of the beginners who learn through online teaching only imitate the motions of the learning targets, and they cannot effectively find out the shortcomings of their own motions and effectively compare the differences between their own motions and those of the learning targets. By offline training camp teaching, most of the coaches usually take a lot of training to make the beginners perform well, this method often ignores the beginners' motivation.

In recent years, with the development of computer vision technology, human posture estimation has also been applied to the sports field[2]. Compared to traditional instructions, it does not require expensive equipment and complex operation and can be analyzed simply by the camera filming the motion process. This provides a new way of basketball study, as the human posture estimation method can be used to identify the weaknesses of beginners' motions and facilitate their improvement[3]. In some studies, experimenters have been photographed in lateral to make a model of their shooting for calculation and analysis[4]. However, in basketball studies, analyzing only the lateral of the body is not enough for the beginners, and the frontal of the body is also necessary. As shown in figure 1-2, skilled players usually hold the ball directly in front of their face before making a shot, but many beginners hold the ball beside their face. This problem cannot be effectively detected by analyzing only from the lateral. In order to protect the individuals, we used a mosaic to obscure the experimenter's facial information.



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	TEAM	GP	W	L	WIN%	MIN	PTS	FGM	FGA	FG%	3PM	3PA	3P%	FTM	FTA	FT%	OREB	DREB	REB	AST	TOV	STL	BLK	BLKA	PF	PFD	+/-
1	Oklahoma City Thunder	82	57	25	.695	48.3	120.1	44.5	89.3	49.9	13.3	34.2	38.9	17.7	21.5	82.5	8.8	33.2	42.0	27.1	12.7	8.5	6.6	5.1	18.8	18.9	7.4
2	Boston Celtics	82	64	18	.780	48.4	120.6	43.9	90.2	48.7	16.5	42.5	38.8	16.3	20.2	80.7	10.7	35.6	46.3	26.9	11.9	6.8	6.6	3.7	16.2	17.3	11.3
3	Minnesota Timberwolves	82	56	26	.683	48.3	113.0	41.3	85.0	48.5	12.6	32.7	38.7	17.8	22.9	77.7	9.4	34.2	43.6	26.6	14.2	7.9	6.1	4.5	18.8	19.9	6.5
4	New Orleans Pelicans	82	49	33	.598	48.1	115.1	42.5	87.4	48.6	12.5	32.6	38.3	17.6	22.8	77.1	10.4	33.6	44.0	27.0	13.0	8.3	4.6	5.2	18.4	18.4	4.4
5	Phoenix Suns	82	49	33	.598	48.2	116.2	42.5	86.1	49.3	12.4	32.6	38.2	18.9	23.4	80.8	10.1	33.9	44.1	27.0	14.9	7.4	6.0	4.5	18.0	19.7	3.1
6	LA Clippers	82	51	31	.622	48.1	115.6	42.4	86.7	48.9	12.6	33.2	38.1	18.3	22.2	82.5	10.0	32.9	43.0	25.6	13.1	7.8	5.0	4.7	18.5	18.7	3.3
7	Golden State Warriors	82	46	36	.561	48.4	117.8	43.7	91.6	47.7	14.8	38.9	38.0	15.6	20.0	78.0	12.1	34.6	46.7	29.3	14.3	7.0	4.6	5.0	19.5	17.9	2.6
8	Los Angeles Lakers	82	47	35	.573	48.4	118.0	43.7	87.5	49.9	11.8	31.4	37.7	18.9	24.2	78.2	8.2	34.9	43.1	28.5	14.0	7.4	5.5	4.8	15.6	19.7	0.6
9	Indiana Pacers	82	47	35	.573	48.1	123.3	47.0	92.7	50.7	13.2	35.3	37.4	16.1	20.5	78.2	10.1	31.4	41.5	30.8	12.9	7.7	5.9	5.4	21.4	18.3	3.0
10	Denver Nuggets	82	57	25	.695	48.1	114.9	44.0	88.8	49.6	11.7	31.2	37.4	15.1	19.9	76.2	10.7	33.7	44.4	29.5	12.6	7.1	5.6	4.8	18.2	17.9	5.3
11	Milwaukee Bucks	82	49	33	.598	48.3	119.0	43.1	88.5	48.7	14.2	38.1	37.3	18.5	23.9	77.4	9.4	34.8	44.2	26.5	12.9	6.8	5.0	4.2	19.2	19.2	2.6
12	Miami Heat	82	46	36	.561	48.2	110.1	39.8	85.6	46.5	12.5	33.7	37.0	18.0	22.0	81.8	9.3	33.0	42.3	25.8	12.7	7.5	3.4	4.7	17.3	18.9	1.8
13	Dallas Mavericks	82	50	32	.610	48.1	117.9	43.1	89.7	48.1	14.6	39.5	36.9	17.0	22.5	75.8	9.7	33.2	42.9	25.7	12.5	6.9	5.0	4.0	18.3	20.3	2.2
14	New York Knicks	82	50	32	.610	48.1	112.8	41.3	88.7	46.5	13.2	35.8	36.9	17.0	21.8	78.0	12.7	32.5	45.2	24.4	13.2	7.5	4.1	5.3	17.6	19.1	4.6

Figure 1.1 NBA 2023-2024 Season Team List[1]

Figure 1.2 Comparison of beginners and skilled players

1.2 Research Objectives and Questions

The purpose of this research is to develop a system based on YOLO Pose to help beginners train for the three-point shots using their physical characteristics and shooting motions.

The specific research questions are as follows.
Research Question 1: How to match a beginner with a suitable training target?
Research Question 2: How to accurately identify the shortcomings of beginners' shooting motions?
Research Question 3: How to improve the training motivation of beginners?
Research Question 4: What is the difference in the effect of analyzing the shooting motions from

both frontal and lateral perspectives compared to analyzing the motions only from the lateral perspective?

1.3 Structure of the Thesis

This thesis is structured as follows:

Chapter 1 Introduction:

Chapter 1 describes how more and more beginners are trying to learn three-point shooting because of the influence of the NBA league. It also describes the advantages of learning three-point shooting through human posture estimation and introduces the shortcomings of traditional learning methods. Finally, the objectives and research questions of this research are presented.

Chapter 2 Related Works:

Chapter 2 describes some of the related studies about basketball instruction and the use of techniques such as human posture estimation or biomechanical analysis for shooting motions. Through previous studies, this research not only analyzes the shooting motions through the lateral but also adds a frontal motion analysis to help beginners train three-point shots in a more effective method.

Chapter 3 Research Design and Methodology:

Chapter 3 presents a system to help beginners with three-point shots. This research mainly utilizes the beginner's physical characteristics as well as the shooting motions keyframes from both frontal and lateral angles to perform the process of matching, recognizing, calculating, and rewarding to improve the three-point shooting percentage by improving the beginner's joint angles. By the YOLOPose, we can visualize the human body's joints and skeleton models, which makes the shooting motions of beginners more intuitive and the calculation of joint angles more convenient.

Chapter 4 Experimentation:

Chapter 4 presents the training results of the training and support system developed in this research in comparison with the training results of the traditional lateral-only motion analysis method, in order to conclude the effects of both frontal and lateral analysis on beginners.

Chapter 5 Conclusion and Future Works:

Chapter 5 summarizes the conclusion of this research and future works.

Chapter 2 Related Works

2.1 Prediction of Basketball Free Throw Shooting by OpenPose

Motion analysis has traditionally relied on video annotation or motion capture techniques[5]: video annotation requires a huge amount of work to disassemble the video frame by frame and manually label the poses. Motion capture techniques require installing multiple sensors on the body, which is complicated and expensive. These methods lead to high cost of data acquisition, which makes it difficult to be widely applied in the field of sports. At CVPR 2017 conference, Carnegie Mellon University (CMU) presented OpenPose[6], As Figure 2.1, it is a real-time skeletal recognition technology that can capture human skeletal points and generate relevant data through a simple webcam and is suitable for generating high-precision skeletal data in multiple environments, with the advantages of low cost and easy operation. It provides new possibilities for statistical diagnosis and dynamic analysis.

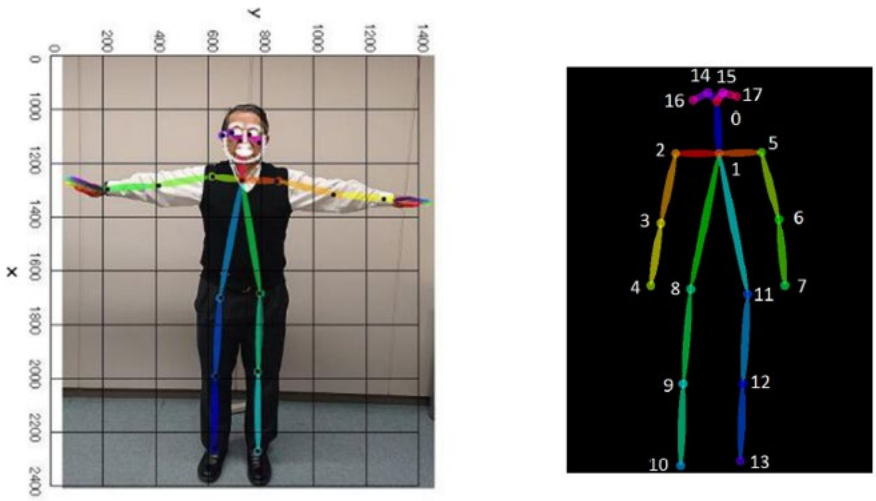

Figure 2.1 Human skeletal points by OpenPose[6]

Masato Nakai et al. collected dynamic skeletal data during basketball free throws by OpenPose and constructed a statistical regression model to predict free throw shooting percentage to validate the accuracy of OpenPose in dynamic motion analysis and its usefulness[7]. A total of 23 basketball players (including members of high school basketball teams and basketball enthusiasts) were recruited, and 51 records were generated through 2-3 free throw trials. Two-dimensional skeletal data were generated using OpenPose, and a logistic regression model was used to predict the free throw results, obtaining an AR (Accuracy Ratio) of 41%, indicating significant model prediction accuracy. Real-time shooting probability display and difference analysis between beginners' and skill players' motions were also realized based on OpenPose's model.

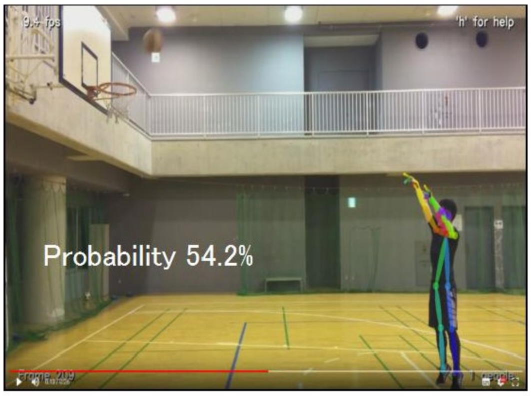

Figure 2.2 Real-time shooting probability display[7]

This research demonstrates the efficiency and utility of OpenPose in dynamic motion recognition. It enables the acquisition of high-quality skeletal data at low cost and provides a high-quality tool for motion analysis, which can significantly reduce the time and costs of traditional methods.

2.2 Analyzing the biomechanical characteristics of the three-point shooting motion in basketball

The aim of this research was to analyze the motion characteristics of three-point shooting through biomechanical methods in order to improve athletes' shooting performance and motion efficiency, as well as to reduce potential sports injuries[8]. The subjects of the research were 20 athletes from Dubas Basketball Club, Magelang Regency, Indonesia, and finally 10 eligible U-21 male athletes were screened. Motion analysis of the videos was performed using Kinovea 0.9.4 software. Data were processed through IBM SPSS 25 software. As shown in Table 2.1,it includes knee, elbow, and shoulder joint angles, jump height, and ball speed. The research covered three shooting phases: preparation, shot, and follow-through action.

It was found that a too-large shoulder joint angle would result in a short shot, while a too-small shoulder joint angle might cause the ball to bounce too far. Meanwhile, a suitable knee angle helps to optimize the ball thrust and the success rate of the shot.

Table 2.1 Kinematic data for three-point shooting[8]

n = 10	**Mean ± Std. Deviation**	**Min**	**Max**
Total time (s)	2.83 ± 0.79	1.73	4.46
Preparation			
Knee flexion angle (°)	103.04 ± 12.38	82.5	121.6
Elbow flexion angle (°)	67.63 ± 7.89	57.1	86.8
Release			
Knee extension angle (°)	166.68 ± 9.49	150.7	179.2
Shoulder extension angle (°)	113.52 ± 13.98	91.9	136.0
Elbow extension Angle (°)	135.39 ± 13.91	114.4	152.7
Jump height (m)	0.54 ± 0.13	0.34	0.73
Ball height (m)	6.05 ± 0.50	4, 97	6.48
Ball time (m)	1.85 ± 0.45	1	2.4
Ball velocity (m/s)	4.00 ± 1.20	2.81	6.75
Follow-through			
Knee angle (°)	164.27 ± 4,81	156.7	171.7
Shoulder angle (°)	134.83 ± 7.91	121.6	145.5
Elbow angle (°)	170.52 ± 4.97	161.6	178.4

Studies have shown that biomechanical analysis plays an important role in improving motion efficiency and preventing sports injuries. The difficulty of the three-point shot lies in the precise control of the distance and the angle of the shot, especially the angle of the shoulder and knee, which significantly influence the flight path of the ball and the shooting percentage.

2.3 Influence of Physical Education Models on Basketball Performance

Siedentop proposed the physical education model to develop students into athletes with skills, tactical understanding, and sports knowledge through extended teamwork and formal game experiences[9]. This research used a basketball course to validate the practical effects of the physical education model, focusing on student changes in three areas: game efficiency (GEI), offensive performance (BOGPI), and sports knowledge. Layne and Yli-Piipari conducted a research on the application of the physical education model in a college basketball course to examine its effects on student game performance and sports knowledge development[10]. This research fills a gap in the research on the physical education model in college and proposes that the model has significant effects in enhancing students' offensive performance and motor knowledge.

The participants of this research were 36 students from a southeastern U.S. university, and the final population analyzed was 25 students, 22 males and 3 females. The 25 students were divided into two groups; 13 were in the physical education group and 12 were in the traditional education group. There was a total of 28 sessions and each session was 85 minutes in length. The physical education group used a team competition that included preliminaries, official games, and wrap-up activities, with students assuming a variety of roles such as team captain, referee, and statistician. The traditional group, on the other hand, only practiced skills and randomized competitions without recording scores.

The data collected in this research included: 1. Recording the match through video and counting the efficiency index of the match after the match. 2. Offensive game performance through play execution and decision-making ability. 3. A basketball knowledge test covering basketball history, rules, and terminology. Analysis of covariance (ANCOVA) was used to compare the difference in performance between the two groups before and after the season.

The following major conclusions were ultimately drawn:

1. Game Efficiency: Although students' game efficiency increased in the physical education model group and decreased in the traditional education group, the difference did not reach statistical significance ($F = 2.65$, $p = 0.118$).

2. Offensive performance: Students in the motor education model group showed significant improvement in offensive performance, with overall BOGPI scores increasing from 4.68 to 7.46, whereas there was almost no change in the traditional instruction group ($F = 26.21$, $p < 0.001$).

3. Motion Knowledge: The physical education model group showed a significant improvement in performance on the content knowledge test (22.6 points), much higher than the improvement in the traditional group (4.9 points) ($F = 25.23$, $p < 0.001$).

This research demonstrated that the physical education model is more helpful for college students to improve their skills and knowledge in a long course than traditional teaching methods, providing empirical evidence for future reforms in physical education pedagogy. The results of this research motivate subsequent researchers to further explore the potential application of the sport education model in different sports. However, the predominantly male and small total sample size of the research may impose limitations on the external validity of the findings. To further validate the generalizability and effectiveness of the physical education model, subsequent studies could expand the sample size to include more females in the research. It is also possible to expand the scope of the research to other sports, such as volleyball, soccer, or track and field. In the future, the sustained effects of long-term SEM adoption on students' exercise interests and health behaviors could also be explored.

2.4 Sport expertise and shot results in Basketball Anticipation

Motion anticipation, the ability to predict the outcome of an event, plays a critical role in basketball. For example, accurately predicting whether a free throw will succeed enables players to prepare for subsequent motions (e.g., rebounding or defense). While sport expertise has been shown to improve anticipation abilities, how this advantage manifests across different temporal phases of an motion remains unclear. This study aimed to evaluate how shot results and temporal phases influence the predictive performance of individuals with varying levels of basketball expertise (collegiate players, recreational players, and non-athletes)[11].

This research examines how sport expertise and shot results influence basketball players' ability to anticipate free-throw outcomes. Eighty-eight male participants (30 college players, 28 recreational players and 30 non-athletes) were tested on four phases of a free throw, including shooting, rising, high point and falling, as shown in Figure 2.3.

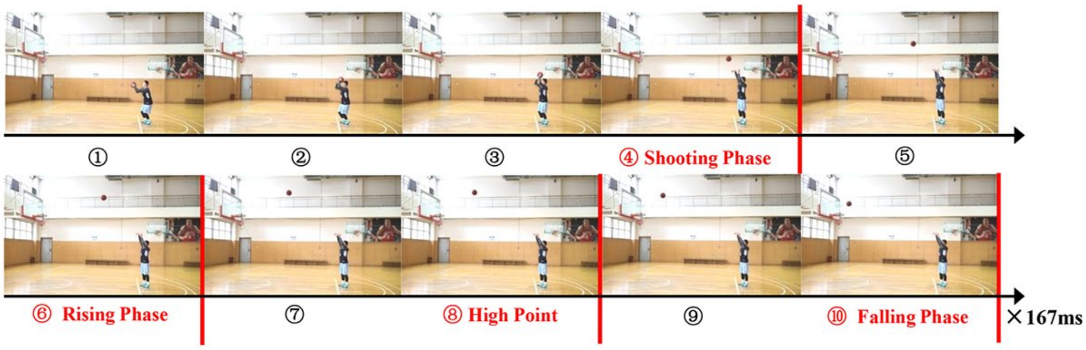

Figure 2.3 Example of the experimental stimuli[11]

The results are shown in Figure 2.4 and Figure 2.5.

Impact of Temporal Phase: During the falling phase, collegiate players (M = 0.71) and recreational players (M = 0.65) exhibited significantly higher accuracy than non-athletes (M = 0.59).

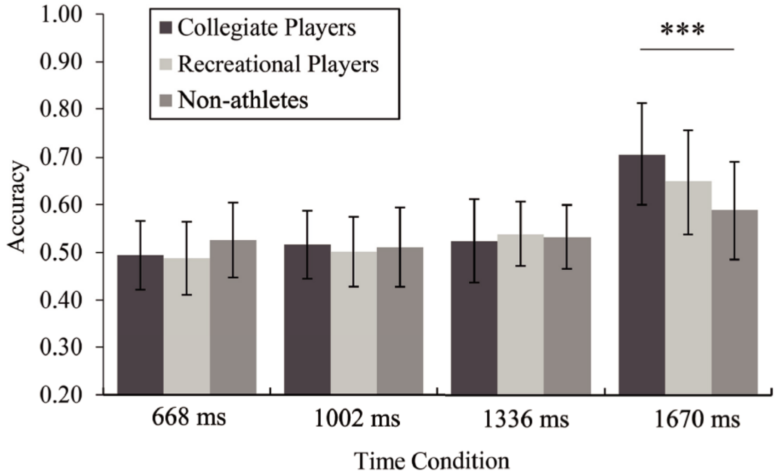

Figure 2.4 Accuracy (mean±*SD*) under each temporal condition per group[11]

Impact of Shot Results: For successful shots, collegiate players (M = 0.69) showed significantly higher accuracy than non-athletes (M = 0.60).

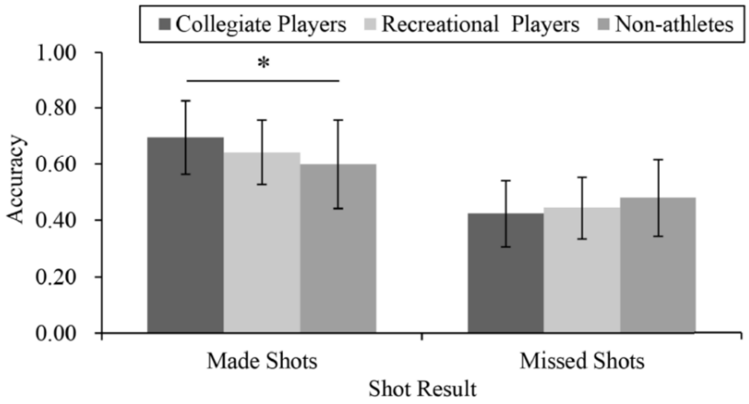

Figure 2.5 The accuracy (the mean±*SD*) of each shot result per group under all-time conditions[11]

Results indicated that collegiate and recreational players demonstrated significantly higher accuracy than non-athletes during the falling phase, while no significant differences were observed in the other phases. Additionally, for successful free throws, both collegiate and recreational players showed higher prediction accuracy than non-athletes. The study revealed that experienced players require more detailed information to make accurate judgments and highlighted the independence of experts' judgment biases for successful shots from the temporal phase.

2.5 Summary

Through OpenPose and other human posture estimation tools, we can obtain human skeleton models with low cost and high quality and apply them in basketball, which has obvious advantages compared with the motion capture and other traditional methods. Secondly, when shooting three-pointers, the knee and shoulder joints have a significant effect on the shooting percentage, so it is feasible to improve the joint angles to improve the shooting percentage of three-pointers. The analysis of covariance comparing the physical education model and the traditional teaching method can effectively compare the differences between the two methods, which provides ideas for the statistical method of this research. Finally, defining the phases of the shot in the video provides us with a reference for obtaining keyframes.

The originality of this research is that it makes up for the shortcomings of the related studies. First, we propose a matching subsystem that can match beginners with suitable skilled players as learning targets based on their physical characteristics. Secondly, we improved the shooting angle, not only from the lateral only but also in the frontal and the lateral at the same time, so that the human skeleton model is more completed. We also included the elbow joint in this research, which is also important in the shooting motions. Finally, we do not only pursue achievement in training but also pay more attention to the motivation of the beginners, so that beginners will not be bored with training the three-point shots.

Chapter 3 Research Design and Methodology

3.1 Proposed method

As Figure 3.1 shows, the proposed method consists of a system that by importing beginner's physical characteristics and keyframes in both frontal and lateral perspectives, the goal is to improve the three-point shooting percentage by improving the angle of the joints. The system is divided into three parts:

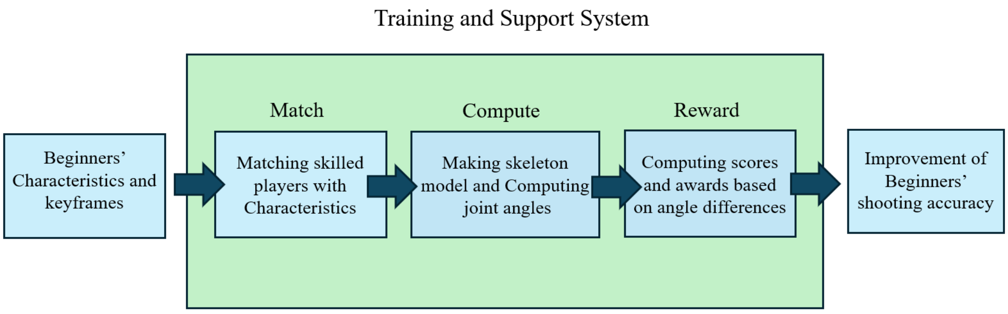

Figure 3.1 The system's workflow

Matching subsystem: After the beginners import physical characteristics such as shooting motions, left and right hand habits, gender, height, weight, and age, the beginners are matched with a training target with similar data from a database of skilled players, because it will be difficult for beginners to utilize the physical characteristics and shooting motions of the learning target if they have a big difference between those of the learning target. Therefore, selecting an appropriate model for a skilled player is necessary. These data are assigned weights based on the degree of influencing the training effect. The matching weights from highest to lowest are gender, left and right-hand habits, Shooting motions, height, weight, and age.

Computational subsystem: Import the keyframes of the shooting videos, through YOLOPose. The characters in the keyframes are subjected to target detection and key points prediction, and the key points of the human body and the skeleton model are output. The mathematical principle of vector dot product and formula is used to calculate the angle of the two straight lines formed by the three key points, which is the angle of the joint.

Reward subsystem: A rubric is developed based on the joint angles of skilled players. The smaller the difference between the import beginner's joint angles get the higher the score. Also, the more balls hit, the higher the score will get. The score is used to get better-quality basketball for training. In this way we hope to increase the training motivation of beginners.

3.2 Matching subsystem

3.2.1 Database

The matching system in this research is mainly built from the skilled player database, as shown in Figure 3.2. We imported physical characteristics of skilled players obtained before the experiment into the matching system:

```
def match_player(age, height, weight, sex, shoot_form, handedness):
    players = [
        {"id": "A01","sex":"Male", "age": [illegible], "height": [illegible], "weight": [illegible], "shoot_form": "1.5 Motion", "handedness": "Right-handed"},
        {"id": "A02","sex":"Male", "age": [illegible], "height": [illegible], "weight": [illegible], "shoot_form": "2 Motion", "handedness": "Right-handed"},
        {"id": "A03","sex":"Male"," age": [illegible], "height": [illegible], "weight": [illegible], "shoot_form": "1.5 Motion", "handedness": "Right-handed"},
        {"id": "A04","sex":"Male", "age": [illegible], "height": [illegible], "weight": [illegible], "shoot_form": "1 Motion", "handedness": "Left-handed"},
        {"id": "A05","sex":"Male", "age": [illegible], "height": [illegible], "weight": [illegible], "shoot_form": "1 Motion", "handedness": "Right-handed"},
        {"id": "A07","sex":"Male", "age": [illegible], "height": [illegible], "weight": [illegible], "shoot_form": "1 Motion", "handedness": "Right-handed"},
        {"id": "A08","sex":"Male", "age": [illegible], "height": [illegible], "weight": [illegible], "shoot_form": "1.5 Motion", "handedness": "Right-handed"},
        {"id": "A10","sex":"Male", "age": [illegible], "height": [illegible], "weight": [illegible], "shoot_form": "1 Motion", "handedness": "Right-handed"},
    ]
```

Figure 3.2 Database of skilled players

A total of eight skilled players' physical characteristics were finally used in this research, which were gender, age, height, weight, Shooting motions, and right and left-handed habits. Among these characteristics, shooting hand habits and shooting motions are the most important, different shooting hand habits and shooting postures may lead to different shot release sequences and shot release styles. There are two main types of shooting hand habits. They are determined by whether the player is left-handed or right-handed. Shooting motions are classified into 3 types, 1 Motion, 1.5 Motion and 2 Motion. They are classified according to the action fluidity, pause point and release speed in the shooting process. Table 3.1 lists their differences.

Table 3.1 Difference between 1, 1.5 and 2 motion

Shooting Motion	Action Fluidity	Pause Point	Release Speed
1 Motion	Most fluid	None	Fastest
1.5-Motion	Relatively fluid	Slight pause (chest or shoulder)	Relatively fast
2 Motion	Least fluid	Clear pause (above head)	Slowest

Our main purpose in collecting these physical characteristics was that these physical characteristics have a big influence on the learning of three-point shooting. When the genders of the beginners and skilled players are different, the effect of the strength on the three-point shooting percentage cannot be ruled out because the strength levels of male and female are different, and the strength of the male skilled players may not be applicable to the female beginners. When beginners and skilled players have different shooting motions and left- and right-handed habits, their motions will be obviously different in the same shooting phase, which is not conducive to obtaining the key frames of the same shooting phase for analysis and increases the difficulty of the experiment. When there is a big difference between the height, weight, age of beginners and skilled players, there will be a big difference between the arm span, muscle mass and athletic ability of skilled players and beginners, and the three-point shooting motions training will be difficult to complete due to the constraints of the physical characteristics and the expected results cannot be achieved. However, different physical characteristics have different degrees of influence on matching, and we will specify the logic of this matching subsystem in the next section.

3.2.2 Matching logic

We assign different matching weights to each type of physical characteristic. As shown in Figure 3.3, the weights are: gender, left and right-handed habits, Shooting motions, height, weight, and age, in descending order.

```
# Normalize numerical attributes (age, height, weight) and calculate similarity
def calculate_similarity(player):
        age_diff = abs(player["age"] - age)
        height_diff = abs(player["height"] - height)
        weight_diff = abs(player["weight"] - weight)

        # Add penalties for mismatched categorical attributes with adjusted weights
        sex_match = 0 if player["sex"] == sex else 10
        handedness_match = 0 if player["handedness"] == handedness else 5
        shoot_form_match = 0 if player["shoot_form"] == shoot_form else 3

        # Weighted sum of differences
        return sex_match + handedness_match + shoot_form_match + height_diff / 10 + weight_diff / 10 + age_diff / 20

# Find the player with the smallest similarity score
best_match = min(players, key=calculate_similarity)
return best_match
```

Figure 3.3 Logic of the matching system

We calculate the similarity scores of the two in the following mathematical operations.

$$SS = d_1+d_2+d_3+wd_4+wd_5+wd_6 \quad (1)$$

where d_1 is sex match, d_2 is handedness match, d_3 is shoot form match, wd_4 is | beginner's height – skilled player's height | / 10, wd_5 is | beginner's weight – skilled player's weight | / 10, wd_6 is | beginner's age – skilled player's age | / 20. Skilled player with the lowest score is found to be the most similar target for beginners.

This matching system can quickly and efficiently calculate the best training target for beginners. As shown in Figure 3.4, we take the statistics of beginner B01 into the matching system, and through the calculation, we find the skilled players A08 with the highest similarity to the beginner's physical characteristics, so we choose A08 as the best training target for B01.

```python
# Example usage
age = 27
height = 178
weight = 62
sex = "male"
shoot_form = "1.5 Motion"
handedness = "Right-handed"

best_match = match_player(age, height, weight, sex, shoot_form, handedness)
print(f"The best matching player is: {best_match['id']}")
```

```
The best matching player is: A08
```

Figure 3.4 Example usage of the matching system

3.3 Computational subsystem

3.3.1 Visualization through YOLOPose

YOLOPose is based on an extended version of the target detection model YOLO used for attitude estimation tasks[12][13]. As shown in Figure 3.5, it adds key point regression, which allows it to output the coordinates of 15-17 key points of the human body while detecting objects. It inherits the real-time and high efficiency of the YOLO family for tasks requiring high frame rates. In this research, we need to shoot and analyze the experimenter's shooting motions on the spot, so we choose YOLOPose based on yolov8.

Figure 3.5 Key points regression of the human body by YOLOPose[12]

In this section, we will take skilled player A01 as an example and introduce how to visualize and analyze the keyframes of the shooting process imported into the subsystem. As shown in Figure 3.5, these are the keyframes of the A01 shooting at the top of the arc position. These are selected from the video of his shooting process when his knee angle is the smallest, elbow angle is the smallest, and shoulder angle is the biggest. These are defined as the keyframes of the A01 in the first, second and third stage. We match keyframes in the frontal and lateral motions based on the same seconds in the frontal and lateral videos.

Figure 3.6 Keyframes of the A01 shooting at top arc

```
!pip install ultralytics --upgrade
```

```
import ultralytics
ultralytics.checks()
```

```
!pip install numpy opencv-python pillow pandas matplotlib seaborn tqdm wandb seedir emoji -i https://pypi.tuna.tsinghua.edu.cn/simple
```

Figure 3.7 Installation of packages

As shown in Figure 3.7, this research utilizes the ultralytics library, commonly used for target detection and computer vision tasks, especially in Yolo modeling. When installing the dependency packages, we specified the pip mirror from Tsinghua University to speed up the installation, which greatly accelerated our installation.

```
!yolo pose predict model=yolov8x-pose-p6.pt source=/content/images/A01-1.png device=cpu

Downloading https://github.com/ultralytics/assets/releases/download/v8.3.0/yolov8x-pose-p6.pt to 'yolov8x-pose-p6.pt'...
100% 190M/190M [00:01<00:00, 108MB/s]
Ultralytics 8.3.57 🚀 Python-3.10.12 torch-2.5.1+cu121 CPU (Intel Xeon 2.20GHz)
YOLOv8x-pose-p6 summary (fused): 375 layers, 99,141,280 parameters, 0 gradients, 266.6 GFLOPs

image 1/1 /content/images/A01-1.png: 1280x768 2 persons, 12669.3ms
Speed: 27.7ms preprocess, 12669.3ms inference, 35.7ms postprocess per image at shape (1, 3, 1280, 768)
Results saved to runs/pose/predict
💡 Learn more at https://docs.ultralytics.com/modes/predict
```

Figure 3.8 Analyzation of A01-1.png by yolov8x

We named the keyframe of the first stage of A01's shooting motions A01-1. We use it as an example of subsystem running and use the yolov8x model to visualize and analyze it, and the result is shown in Figure 3.8. Since another skilled player in the distance entered the shooting range, two boxes of predicted characters were generated in this keyframe. However, as shown in Figure 3.9, since the distant character is not complete, the confidence level is only 0.27, while the confidence level of the character of the main subject A01 is 0.93, so it does not affect the effectiveness of this prediction, and the subsequent calculation results.

We identified 15 key points of skilled player A01 and connected them as a model of this skilled player's three-point shot during the lateral first phase. In this keyframe, we aim to calculate A01's right knee joint angle.

Figure 3.9 Skeletal model of A01

To calculate the angle of the knee joint, we need to obtain the coordinates of key points.

```
# Draw keypoints for this bounding box
for kpt_id in kpt_color_map:

    # Get the color, radius, and XY coordinates of the keypoint
    kpt_color = kpt_color_map[kpt_id]['color']
    kpt_radius = kpt_color_map[kpt_id]['radius']
    kpt_x = int(bbox_keypoints[kpt_id][0])  # Convert to int
    kpt_y = int(bbox_keypoints[kpt_id][1])  # Convert to int
```

```
# Draw skeleton connections for this bounding box
for skeleton in skeleton_map:

    # Get the coordinates of the starting point
    srt_kpt_id = skeleton['srt_kpt_id']
    srt_kpt_x = int(bbox_keypoints[srt_kpt_id][0])  # Convert to int
    srt_kpt_y = int(bbox_keypoints[srt_kpt_id][1])  # Convert to int

    # Get the coordinates of the ending point
    dst_kpt_id = skeleton['dst_kpt_id']
    dst_kpt_x = int(bbox_keypoints[dst_kpt_id][0])  # Convert to int
    dst_kpt_y = int(bbox_keypoints[dst_kpt_id][1])  # Convert to int

    # Check if the skeleton connection points are within the bounding box
    if (is_within_bbox(srt_kpt_x, srt_kpt_y, bbox_xyxy) and
            is_within_bbox(dst_kpt_x, dst_kpt_y, bbox_xyxy)):
```

Figure 3.10 Obtention of the key points

As shown in the Figure 3.10, we obtain the coordinates of the key points from the start and end points of the skeleton for plotting the key points and their connecting lines, and the results are shown in Figure 3.11: all the observable joints on the right side of the skilled player A01 are plotted with the numbers 0-16, and the angle of the target right knee joint is calculated to be the number of 12-14-16.

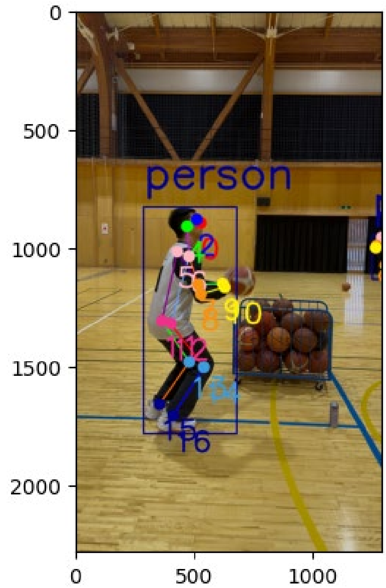

Figure 3.11 A01's joints key points from 0-16

3.3.2 Calculation of joint angles

This section introduces how to calculate the target joint angles as well as key point detection and extraction by means of vectors.

```
def calculate_angle(point1, vertex, point2):

    # Vector 1: from the vertex to point1
    vector1 = np.array(point1) - np.array(vertex)
    # Vector 2: from the vertex to point2
    vector2 = np.array(point2) - np.array(vertex)

    # Calculate dot product and magnitudes
    dot_product = np.dot(vector1, vector2)
    norm1 = np.linalg.norm(vector1)
    norm2 = np.linalg.norm(vector2)

    # Prevent floating-point precision issues, restrict cos value to [-1, 1]
    cos_theta = np.clip(dot_product / (norm1 * norm2), -1.0, 1.0)

    # Calculate angle (in radians)
    angle_rad = np.arccos(cos_theta)

    # Convert to degrees
    angle_deg = np.degrees(angle_rad)
    return angle_deg
```

Figure 3.12 Calculation of the vectors

As shown in Figure 3.12, first, we calculate the dot product and modules of vector1 and vector2, calculate the cosine of the angle using the dot product formula, and restrict the result to the range [-1,1] to avoid out-of-range errors due to floating-point precision issues.

```python
if len(bboxes_keypoints) > 0 :
    bbox_keypoints = bboxes_keypoints[0]

    # Extract coordinates for keypoints 12, 14, and 16
    x12 = int(bbox_keypoints[12][0]) if len(bbox_keypoints) > 12 else None
    y12 = int(bbox_keypoints[12][1]) if len(bbox_keypoints) > 12 else None
    x14 = int(bbox_keypoints[14][0]) if len(bbox_keypoints) > 14 else None
    y14 = int(bbox_keypoints[14][1]) if len(bbox_keypoints) > 14 else None
    x16 = int(bbox_keypoints[16][0]) if len(bbox_keypoints) > 16 else None
    y16 = int(bbox_keypoints[16][1]) if len(bbox_keypoints) > 16 else None

    if all([x12, y12, x14, y14, x16, y16]) :
        print(f"x12: {x12}, y12: {y12}")
        print(f"x14: {x14}, y14: {y14}")
        print(f"x16: {x16}, y16: {y16}")

        # Example coordinates
        point12 = (x12, y12)   # Coordinates of point12
        point14 = (x14, y14)   # Coordinates of point14 (vertex)
        point16 = (x16, y16)   # Coordinates of point16

        # Calculate the angle
        angle = calculate_angle(point12, point14, point16)
        print(f"The angle between point12-point14-point16 is: {angle:.2f}° ")
    else:
         print("Could not calculate angle, not all keypoints were detected.")
else:
    print("No keypoints detected")
```

```
x12: 400, y12: 1321
x14: 538, y14: 1504
x16: 410, y16: 1708
The angle between point12-point14-point16 is: 110.87°
```

Figure 3.13 Calculation of the angles

As shown in Figure 3.13, to calculate the degree of the angle 12-14-16, we extract the coordinates of the key points 12, 14, and 16. If all key points are detected, the angle calculation continues; otherwise, an error message is output. Finally, we calculated the right knee angle of skilled player A01 as 110.87°.

3.4 Reward subsystem

3.4.1 Scoring program

This section focuses on the scoring program of the reward subsystem. It is unfair to score male and female beginners together due to the problem of strength difference between male and female resulting in a big difference in three-point shots performance as well. To solve this problem, the subsystem is designed with two different scoring programs for male and female beginners.

Male beginners:

As shown in Figure 3.14, we take beginner B01 as an example. In the reference angle, enter the shoulder joint angle of 129.82° of the skilled player A08, who is the subject of him, and the shoulder joint angle of 131.19° of himself, and obtain the score by calculating the difference between the two people. When the difference is less than 10°, 20°, and 30°, the corresponding score is 30, 20, and 10. At the same time, if the shot was made, enter “True” and double the number of points. If the shot was not made, enter "False," and the points will not be doubled. In this calculation, the difference between the shoulder joint angle of the beginner B01 and the shoulder joint angle of the skilled player A08 is 1.37 degrees, which is less than 10 degrees, and the shot was not made, so the score is 30.

```
def calculate_score(input_angle, reference_angle=129.82, made_shot=True):

    # Calculate the difference between the input angle and the reference angle
    angle_diff = abs(input_angle - reference_angle)

    # Determine the base score based on the angle difference
    if angle_diff <= 10:
        score = 30
    elif angle_diff <= 20:
        score = 20
    elif angle_diff <= 30:
        score = 10
    else:
        score = 0

    # Double the score if the shot is made
    if made_shot:
        score *= 2

    return score

# Example usage
input_angle = 131.19   # Input angle (in degrees)
made_shot = False   # Whether the shot is made

score = calculate_score(input_angle=input_angle, made_shot=made_shot)
print(f"The obtained score is: {score}")
```

```
The obtained score is: 30
```

Figure 3.14 Scoring program for male beginners

In testing the subsystem before the experiment, we found that it was not too difficult to improve the angle difference to within 30 degrees and that there was a large improvement in the shooting motions. However, it was difficult to improve the angle difference to within 10 degrees. Therefore, we set up this scoring program to give beginners some confidence and at the same time increase the difficulty to challenge.

The time required to calculate the angle of a joint in a keyframe as well as the score is about 5-10 minutes, as the length of this experiment is 1.5 hours, so we only calculate one shot or the closest shot in a set of shootings. To evaluate the whole group of shots, we also included a program for additional scores. As shown in Figure 3.15, x is the total number of goals in the group of shots, and y is the score of individual motions calculated in the previous section. In the case of beginner B01, for example, he did not make any shots in the group, so the value of x is entered as 0, and the value of y is entered as the score of 30 points, finally he gets 30 points in this group.

```
def calculate_score(x, y):

    return 10 * x + y

# Example usage
x = int(input("Please enter the value of x: "))
y = int(input("Please enter the value of y: "))

score = calculate_score(x, y)
print(f"The total score is: {score}")
```

```
Please enter the value of x: 0
Please enter the value of y: 30
The total score is: 30
```

Figure 3.15 Example usage of male beginners

Female beginners:

Female beginners may have difficulty making three-point shots due to a lack of strength[14], even if the angle of the joints when has been effectively improved. Therefore, we have added “Correct shot” to the scoring program for female beginners, which means that the three-point shot falls within the Restricted Area[15]. As shown in Figure 3.16, the “RA” arrow points to the Restricted Area, which is a semicircular area under the basket with a radius of 1.25 meters (4 feet/1.22 meters in the NBA) centered on the center of the rim. Since this area is similar in shape to the three-point line and closer to the basket. Because three-pointers made by female beginners that land in this area are close to the basket, which is defined to be a “Correct shot” and will obtain points.

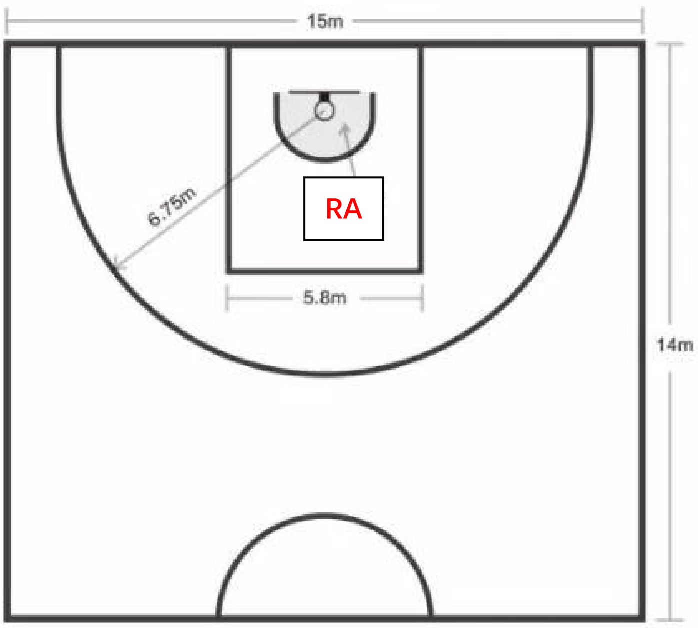

Figure 3.16 Restricted Area

As shown in Figure 3.17, we take the female beginner B20 as an example. Unlike the score program for male beginners, if the shot involved in calculating the angle is correct, the score obtained for this shot will be multiplied by 1.5 times. Enter the knee angle of female beginner B20 as 82.30° and the knee angle of her learning target, skilled A03, as 67.86°, with a difference of 14.44°, which is more than 10° and less than 20°, obtains a score of 20 points, and since the shot missed but landed within the restricted area, the final score is multiplied by 1.5 times as 30 points.

```
def calculate_score(input_angle, reference_angle=67.86, made_shot=True, correct_shot=True):

        # Calculate the difference between the input angle and the reference angle
        angle_diff = abs(input_angle - reference_angle)

        # Determine the base score based on the angle difference
        if angle_diff <= 10:
                score = 30
        elif angle_diff <= 20:
                score = 20
        elif angle_diff <= 30:
                score = 10
        else:
                score = 0

        # Double the score if the shot is made
        if made_shot:
                score *= 2

        # Multiply the score by 1.5 if the shot is correct
        if correct_shot:
                score *= 1.5

        return score

# Example usage
input_angle = 82.30  # Input angle (in degrees)
made_shot = False  # Whether the shot is made
correct_shot = True  # Whether the shot is correct

score = calculate_score(input_angle, made_shot=made_shot, correct_shot=correct_shot)
print(f"The obtained score is: {score}")

The obtained score is: 30.0
```

Figure 3.17 Scoring program for female beginners

Similarly, we added the number of correct shots to the score for the entire group of shots as shown in Figure 3.18. With z representing the number of correct shots, the final score is 60 for the female beginner B20 in this group.

```
def calculate_score(x, y, z):

        return 10 * x + y + 3 * z

# Example usage
x = int(input("Please enter the value of x: "))
y = int(input("Please enter the value of y: "))
z = int(input("Please enter the value of z: "))
score = calculate_score(x, y, z)
print(f"The total score is: {score}")

Please enter the value of x: 0
Please enter the value of y: 45
Please enter the value of z: 5
The total score is: 60
```

Figure 3.18 Example usage of female beginners

3.4.2 Reward program

The reward program for this experiment is based on the scores to provide better quality basketballs as rewards for beginners. The reward balls are shown in Figure 3.19. The brands are Spalding, Wilson, and Molten. These are the brands of basketballs used by the NBA and the JBA(Japan Basketball Association) league. These reward balls are made of better materials, but they do not affect the three-point percentage, only provide a better shooting experience.

Figure 3.19 Reward basketballs

The reward program was divided into control and experimental groups. The beginners in the control group improved their joint angles only through the lateral joint angles only through the lateral joint angles, while the experimental group improved their joint angles through both the lateral and the frontal joint angles. The scores of the control group for the three brands of reward basketballs are set to be more than or equal to 10 points, 30 points, and 50 points. As shown in Figure 3.20, taking the control group beginner B01 as an example, inputting his total score of 30 points, the output result is “Wilson.” Therefore, beginner B01 got two brands of reward basketballs: Spalding and Wilson.

```python
# Control Group
def determine_output(score):

    if score >= 50:
        return "Molten"
    elif score >= 30:
        return "Wilson"
    elif score >= 10:
        return "Spalding"
    else:
        return "No Output"

# Output result based on score
output = determine_output(score)

print(f"The score is: {score}")
print(f"The output is: {output}")
```

```
The score is: 30
The output is: Wilson
```

Figure 3.20 Reward program of the control group

Beginners in the experimental group scored twice by calculating joint angles twice. Therefore, for the experimental group, we doubled the scores of the three brands of reward basketballs to 20, 60, and 100 points. As shown in Figure 3.21, the female beginner B20 in the experimental group was calculated to have a frontal angle score of 0 and a lateral angle score of 60, so the total frontal and lateral scores for this female beginner are 60 points. As shown in the figure, the total score of 60 is inputted, and the output result is "Wilson." Therefore, female beginners in B20 also got two kinds of rewards: basketballs, Spalding, and Wilson.

```python
# Experimental Group
def determine_output(score):

    if score >= 100:
        return "Molten"
    elif score >= 60:
        return "Wilson"
    elif score >= 20:
        return "Spalding"
    else:
        return "No Output"

# Output result based on score
output = determine_output(score)

print(f"The score is: {score}")
print(f"The output is: {output}")
```

```
The score is: 60
The output is: Wilson
```

Figure 3.21 Reward program of the experimental group

Chapter 4 Experimentation

4.1 Experiment introduction

4.1.1 Experimental Purpose and Methods

The experiment evaluated two approaches to train for three-point shots, the traditional approach of analyzing the motion from the lateral only and analyzing the motion from both the front and lateral perspectives. The purpose of this experiment was to investigate which approach was more effective to improve the three-point shooting percentage of beginners. A total of 30 participants were recruited for this research, 10 skilled players from Jaist international basketball club and 20 beginners from Jaist. The skilled players were 10 males, and the beginners were 13 males and 7 females.

The definition of skilled players and beginners in this experiment was based on the “Chinese Basketball Association Basketball Skill Rating Management Method”[16]. The basketball skill rating was categorized into twelve levels, from level one to level twelve, corresponding to beginner, intermediate and advanced levels. The rating standard covers ten categories, including dribbling, passing, shooting, individual defense, rebounding and so on. It provided basketball enthusiasts with a clear reference of skill levels. We designated basketball enthusiasts at the level as beginners and defined intermediate and above as skilled players Before a skilled player was selected, he or she had a percentage requirement during the experiment, which will be introduced in the next section.

This experiment was approved by the JAIST Life Science Committee, the approve number is “人06-067”.

4.1.2 Research Design

This experiment was conducted at the Jaist gymnasiums using half of the basketball court. As shown in Figure 4.1, we modeled the location of the shot in the NBA All-Star Three-Point Contest by marking five spots with red markers, which were the two bottom corners, the two 45-degree corners, and the top of the arc. This experiment was conducted by grouping the skilled and beginners. The experimental task for the skilled players was to participate in three groups of three-point shots, each group with 25 shots, for a total of 75 shots. The experimental task for beginners was to participate in four groups of shots, with the first and fourth groups with 25 shots each, and the second and third groups with 10 shots each, for a total of 70 shots.

Figure 4.1 Jaist gymnasiums

This experiment used cell phone cameras, and the shooting positions were the frontal and lateral of the experimenters. The shooting position of the frontal was the direction of the experimenter facing the basket, and the camera position was in the center of the experimenter and the basket. The shooting equipment was iPhone7 PLUS, which is fixed by a tripod. The shooting position of the lateral was the direction of the experimenter's shooting hand. For example, the shooting position of the experimenter who shoots with his right hand was on the right lateral of the experimenter, and the shooting position of the experimenter who shoots with his left hand was on the left lateral of the experimenter. The shooting equipment was iPhone14 Pro Max, which the experiment implementer used.

Skilled players:

In order to ensure the reliability of our skilled players, we conducted a selection process before the formal experiment, to select skilled players with a certain level of three-point shooting ability. In this selection, our targets were Jaist International Basketball Club members. We observed the three-point shooting tendency and three-point shooting ability of each member through the weekly games of the club activities. Finally, we selected 10 skilled players with certain three-point shooting abilities to take part in the experiment and numbered them from A1 to A10. In order to confirm their three-point shooting ability, we counted their percentage in the formal experiment.

Before the start of the formal experiment, the physical characteristics of the 10 skilled players were collected by questionnaires, and the results are shown in Table 4.1. The physical characteristics included gender, age, height, weight, years of experience, best performance, left- and right-handed shooting habits, and shooting position. For the protection of individuals' information, we did not show their height, weight, and age in the table. The 10 skillful players were all male, and their ages ranged from 24 to 30, with an average age of 26.

Basketball experience ranged from 8 to 15 years with an average of 10.9 years of experience. The best score was a personal best in a three-point shooting practice during Jaist international basketball club activities, and skilled players A08 and A09 were missing this data because they had not participated in the practice.

Table 4.1 Physical characteristics of skilled players

ID	Genders	Years	Record	Motion	Hand
A01	Male	10	16/25	1.5	Right
A02	Male	15	16/25	2	Right
A03	Male	8	18/25	1.5	Right
A04	Male	12	17/25	1	Left
A05	Male	9	12/25	1	Right
A06	Male	10	8/25	1.5	Right
A07	Male	10	12/25	1	Right
A08	Male	12	0/0	1.5	Right
A09	Male	12	0/0	1.5	Right
A10	Male	11	13/25	1	Right

In the formal experiment, the goals for each position were recorded and the best record for each skilled player was recorded after all shots were taken. The results are shown in Table 4.2. One shooting motion was selected from best record position as the shooting model for that skilled player.

Table 4.2 Results of the skilled players

ID	Left Corner	Left Wing	Center Arc	Right Wing	Right Corner	Best	Total
A01*	5/15	6/15	9/15	6/15	7/15	Center Arc 9/15	33/75
A02*	2/15	2/15	5/15	2/15	5/15	Right Corner 5/15	16/75
A03*	3/15	7/15	5/15	4/15	8/15	Right Corner 8/15	27/75
A04*	3/15	5/15	6/15	3/15	2/15	Center Arc 6/15	19/75
A05	1/15	1/15	2/15	3/15	1/15	Right Wing 3/15	8/75
A06*	4/15	4/15	3/15	6/15	4/15	Right Wing 6/15	20/75
A07*	3/15	3/15	4/15	3/15	4/15	Center Arc 4/15	17/75
A08*	3/15	1/15	4/15	2/15	3/15	Center Arc 4/15	13/75
A09	1/15	1/15	4/15	2/15	1/15	Center Arc 4/15	9/75
A10*	6/15	4/15	4/15	3/15	5/15	Left Corner 6/15	22/75

According to the table, the average number of goals for the 10 skilled players was 18.4. 4 skilled players had a number of goals below the average. In order to ensure the validity as a learning target, we analyzed the Shooting motions of these 4 skilled players and found that the shooting motions of two skilled players, A05 and A09, among these 4 skilled players had big problems, such as a small angle of the shoulder, which also led to their lower percentage. Through comprehensive judgment, we did not think their shooting motions were useful for beginners and did not adopt the shooting models of the two. The rest of the adopted skilled players were marked with *.

As introduced in section 3.3.1, we stored all the keyframes and joint angles of each skilled player collected into the skilled player's dataset in a folder. The storage format is shown in Figure 4.2, taking skilled player A01 as an example.

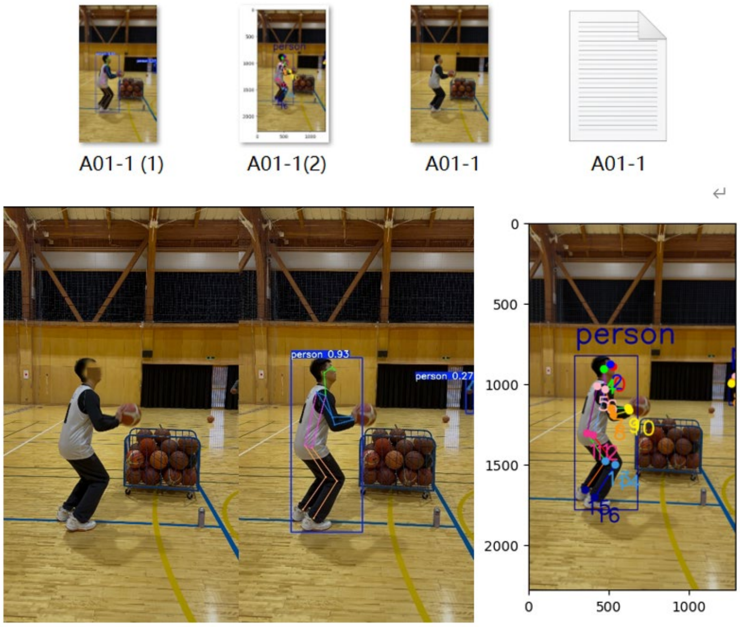

Figure 4.2 Dataset of A01

The text file recorded the angle of the knee joint on the latter of skilled player A01 during the first phase of the three-point shot.

Beginners:

In this experiment, beginners were divided into control and experimental groups. The control group followed the previous research method and only photographed the shooting motions of the beginners from the lateral. In the experimental group, the shooting motions of beginners were photographed from both lateral and front angles according to the methodology of this research.

Before the experiment, 20 beginners were applied to a questionnaire, and the results are shown in Table 4.3. The physical characteristics included gender, age, height, weight, and shooting habits of both left and right hands. As skilled players, for the protection of individual information, we did not show their height, weight, and age on the table. Since most of the beginners were exposed to three-point shooting for the first time, the beginners tried to shoot three-points before the experiment, and we judged the type of their motion types according to their shooting motions and recorded them. The physical characteristics were imported into the matching subsystem, and the beginner was matched with the most suitable skilled player as the training target.

Since training for three-point shots is a long process, it was difficult to improve all the joint angles of the beginners in the 1.5 hours of this experiment. Therefore, in this experiment, we diagnosed the most problematic shooting phase for each beginner and aimed to improve the joint angles for this phase. At the same time, we did not neglect the other phases. We showed and explained the differences between the motions of beginners and their training target in the other phases, with the secondary goal of improving the overall shooting motions.

Unlike the data set of the skilled players, in the data set of the beginners, the information recorded in the text file of each beginner includes the skilled player's number of the training target, the target joint for improvement, the first group of shooting percentage and the target joint angle, the second group of target joint angles, the third group of target joint angles, the third group of scores, and the fourth group of target joint angles and shooting percentage.

Table 4.3 Physical characteristics of beginners

ID	Genders	Motion	Hand	Group
B01	Male	1.5	Right	control
B02	Male	1.5	Right	control
B03	Male	1	Right	experimental
B04	Male	1.5	Right	experimental
B05	Male	1.5	Right	control
B06	Male	1.5	Right	experimental
B07	Female	1.5	Left	control
B08	Female	1.5	Right	control
B09	Male	1.5	Right	experimental
B10	Male	2	Right	experimental
B11	Male	1.5	Right	experimental
B12	Male	1.5	Right	control
B13	Male	1.5	Right	experimental
B14	Male	1.5	Right	control
B15	FeMale	1.5	Right	control
B16	FeMale	1.5	Right	experimental
B17	FeMale	1.5	Right	control
B18	FeMale	1.5	Right	control
B19	Male	1.5	Right	experimental
B20	FeMale	1.5	Right	experimental

4.2 Flow of the Experiment

Experimental Process for Skilled players (Total Duration: 1.5 hours)

0) Explained the experiment and completed the informed consent form (10 minutes)
Explained in detail to the skilled players the purpose of the experiment and the precautions to be taken in the experiment. The skilled players signed the consent form indicating his/her willingness to participate in the experiment.

1) Explained the experimental procedure in detail to the skilled players and filled in the pre-experimental questionnaire (10 minutes)
Explained the experimental procedure to the skilled players and counted the physical characteristics of the skilled players in the form of a questionnaire.

2) Warm-up activities and shooting attempts by skilled players (10 minutes)
In order to ensure the shooting quality of the skillful players in the experiment, skilled players had warm-up activities before the beginning of the experiment.

3) The first set of three-pointer shooting (10 minutes)
The first set of shots consisted of the skilled players taking 5 shots at each of the 5 selected positions, for a total of 25 shots.

4) First break (10 minutes)
Skilled players took a break between groups to relax.

5) Second Three-Point Shooting (10 minutes)
The second shooting group consisted of the skilled players taking 5 shots at each of the 5 selected positions, for a total of 25 shots.

6) Second break (10 minutes)
The skilled players took a break between groups to relax.

7) Third set of three-point shooting (10 minutes)
The third shooting group consisted of the skilled players, who took 5 shots at each of the 5 selected positions, totaling 25 shots.

8) Post- experimental questionnaire (10 min)
A questionnaire was used to get feedback and suggestions from the skilled players.

The pre-experiment questionnaire for the skilled players as shown in questionnaire 1 in the appendix consists of the following questions:
1. Physical characteristics (gender, age, height, weight, left and right-hand habits)
2. Years of basketball experience
3. Record of three-point shots
4. Shooting motion

The post-experiment questionnaire for skilled players as shown in questionnaire 2 in appendix consists of the following questions:
1. Difficulty of the experiment
2. Clarity of experimental content
3. Fatigue felt after the experiment
4. Degree of stress felt as a learning target
5. Other suggestions for the experiment

Experimental Process for Beginners (Total Duration: 1.5 hours)

0) Explained the experiment and completed the informed consent form (10 minutes)
Explained in detail to the beginners the purpose of the experiment and the precautions to be taken in the experiment. Beginners sign the consent form indicated their willingness to participate in the experiment.

1) Explained the experimental procedure in detail to beginners and filled in the pre-experimental questionnaire (10 minutes)
Explained the process of the experiment to the beginners and took their physical characteristics in the form of a questionnaire.

2) Three-point shooting practice (10 minutes)
Showed three-point shooting to beginners, who prepared and practiced before the experiment begins.

3) First group of three-point shooting (10 minutes)
The first group of shots consisted of the beginners' taking 5 shots at each of the 5 selected positions, for a total of 25 shots.

4) First break (10 minutes)
Beginners took a break between groups to relax.

5) Second group of three-point shooting (5 minutes)
The second shooting group was for beginners to take 10 shots from 1 selected position.

6) Second break (5 minutes)
Beginners took a break between groups to relax.

7) Third group of 3-point shooting (5 minutes)
The third shooting group is for beginners to take 10 shots at 1 selected position.

8) Third rest (5 minutes)
Beginners took a break between groups to relax.

9) Fourth group of 3-point shooting and shooting (10 minutes)
The fourth shooting group consisted of beginners taking 5 shots at each of the 5 selected positions, for a total 25 shots.

10) Post- experimental questionnaire (10 minutes)
A questionnaire was used to get experimental feedback and suggestions from beginners.

The pre-experimental questionnaire for beginners as shown in questionnaire 1 in the appendix consists of the following questions:
physical characteristics (gender, age, height, weight, left and right-hand habits)

The post-experimental questionnaire for beginners as shown in questionnaire 3 in the appendix consists of the following questions:
1. Difficulty of the experiment
2. Clarity of experimental content
3. Fatigue felt after the experiment
4. The utility of this experiment in learning three-point shooting
5. Interests of the reward system
6. Other suggestions for the experiment

The beginner took 4 rounds of shots, the first round took 5 shots at each point, a total of 25 shots. After the first round of shooting, firstly, we recorded the initial shooting percentage of the beginner, secondly, according to our three stages of shooting, we got the key frames of each stage, and then we compared these key frames with the corresponding key frames of the skilled players, diagnosed the most problematic frame and calculated the angle of the joints that we aimed to improve in this stage. For example, beginner B01 is analyzed by comparing with his training target A08, and it is concluded that the beginner has the biggest difference between his training target was his jumping motion, and the main reason for the difference was the difference of shoulder joint angle. Therefore, we set the main goal of this beginner in this research as the shoulder joint angle in the jump shot phase, and we calculated the shoulder joint angle of this beginner as his initial data. After the first round of shooting, we did not show the beginner the specific degree of the joint angle of the training target. However, we told the beginner to learn mainly by observing the motion difference with eye contact.

The second round of shooting was a test for beginners after their first group. The beginner took 10 shots at the best record point of the corresponding skilled players, and at the end of the shot, we selected the shot that he/she scored or was closest to the goal for the calculation of the angle of the target joint. We showed the specific degree of the angle for the target so that the beginner could understand the difference.

The third round of shooting was a test for beginners after the second group. There were still 10 shots at the same spots as the second round and the target angle was calculated. Also, the third shooting round was a bonus round. The target angle for beginners calculated in the third round is entered into the reward subsystem and compared with the corresponding target angle of skilled players, and the score is based on the size of the difference and the number of goals in the third round, and the level of the reward was determined by the score obtained.

The fourth round of shooting was the final test. The same rules as in the first group were applied and a total of 25 shots were made. The results of the fourth-round target joint angles and hits were recorded and compared to the first-round data. The changes in target joint angle and percentage before and after training were observed. Whether the percentage improved or not was used as a test of the effectiveness of this three-point shooting training.

4.3 Experimental results

The results of the experiment were shown in table 4.4.

Table 4.4 Results of the beginners

ID	Group	Target	Genders	Joint	Result1	Side Angle1	Front angle1	Result4	Side Angle4	Front angle4	Target Side Angle	Target Front Angle
B01	control	A08	Male	shoulder	0/25	104.33		0/25	131.19		129.82	
B02	control	A01	Male	elbow	1/25	123.78		1/25	132.07		76.68	
B03	experimental	A07	Male	shoulder	1/25	143.48	174.53	5/25	129.13	172.77	144.08	173.1
B04	experimental	A08	Male	shoulder	1/25	119.00	100.64	3/25	133.44	167.15	129.82	173.32
B05	control	A03	Male	knee	1/25	115.59		0/25	120.30		99.25	
B06	experimental	A04	Male	elbow	0/25	81.26	43.41	0/25	71.78	73.58	89.44	89.54
B07	control	A05	Female	shoulder	0/25	125.19		0/25	134.99		146.42	
B08	control	A03	Female	elbow	0/25	49.69		0/25	67.20		67.86	
B09	experimental	A02	Male	elbow	0/25	58.30	10.05	4/25	54.22	14.06	97.77	82.97
B10	experimental	A02	Male	elbow	0/25	71.66	120.54	1/25	93.53	128.80	97.77	82.97
B11	experimental	A08	Male	knee	2/25	100.39	176.17	3/25	77.01	179.80	108.19	148.77
B12	control	A08	Male	knee	0/25	100.46		3/25	99.57		108.19	
B13	experimental	A05	Male	elbow	0/25	53.55	54.45	3/25	77.68	87.16	67.28	32.8
B14	control	A02	Male	shoulder	1/25	143.46		1/25	137.22		136.24	
B15	control	A03	FeMale	elbow	0/25	84.37		0/25	64.99		67.86	
B16	experimental	A03	FeMale	elbow	0/25	71.60	50.64	0/25	81.26	19.34	67.86	7.59
B17	control	A03	FeMale	knee	0/25	92.49		0/25	85.89		99.25	
B18	control	A03	FeMale	elbow	0/25	55.60		0/25	51.51		67.86	
B19	experimental	A01	Male	knee	0/25	94.57	166.16	2/25	135.88	151.57	110.87	139.67
B20	experimental	A03	FeMale	elbow	0/25	65.31	34.28	0/25	82.30	53.81	67.86	7.59

As previously introduced, the beginners in this experiment were divided into experimental and control groups. The main data counted in Table 4.5 are the shooting percentage of the first group's shots as well as the fourth group's shots and the angle of the target learning joint. We first counted the improvement of the angle and shooting percentage of the beginners in both groups.

Table 4.5 The improvement of the angle and shooting percentage

Group	Experimental	Control
Numbers	10	10
Average Angle Improvement - Lateral	7.711	2.997
Average Angle Improvement - Frontal	11.717	
Average Shooting Percentage Improvement	8.50%	1.60%
Standard Deviation - Lateral	20.061	13.337
Standard Deviation - Frontal	27.396	
Standard Deviation - Percentage	0.058	0.061

The results showed that the experimental group had a better improvement in average angle and average shooting percentage than the control group. To compare the significant difference between the experimental group's training through both frontal and lateral perspectives and the control group's learning only from the lateral perspectives of the improvement in the shooting percentage, we used Wilcoxon Rank-Sum Test, and the results are shown in Table 4.6.

Table 4.6 Results of Wilcoxon Rank-Sum Test

	Statistic	p-value
Percentage Improvement	-2.305	0.021

Since the P-value is less than 0.05, it indicated that the difference between the experimental group and the control group increased in shooting percentage is statistically significant. This indicated that the experimental group was significantly better than the control group after adding frontal angle training.

According to the experimental results, no female beginners made the shot in this experiment, and according to the introduction in section 3.4.2, we regarded a female beginner's shot that landed within the restricted area as a correct shot, as shown in table 4.7, we recorded the number of their correct shots.

Table 4.7 Results of female beginners correct shots

Group	Target	Genders	Joint	Result1	Result4
control	A05	Female	shoulder	16/25	23/25
control	A03	Female	elbow	18/25	21/25
control	A03	FeMale	elbow	21/25	23/25
experimental	A03	FeMale	elbow	19/25	23/25
control	A03	FeMale	knee	19/25	13/25
control	A03	FeMale	elbow	5/25	17/25
experimental	A03	FeMale	elbow	11/25	19/25

As shown in Table 4.8, we also calculated the average of correct three-point shots for the control and experimental groups of female beginners. Percentage 1 represents the average percentage of first group of correct shots taken by female beginners and Percentage 4 represents forth group. We found that the average of correct shots for both groups of female beginners improved through this research, with an improvement of 14% for the control group and 24% for the experimental group. It indicated that the experimental group of female beginners was also had a better improvement than the control group after adding frontal angle training.

Table 4.8 Average number of correct shots

Group	Number	Percentage1	Percentage4
Control	5	63.2%	77.6%
Experimental	2	60.0%	84.0%

4.4 Questionnaire results

In this research, post-experimental questionnaires for both beginners and skilled players were conducted. The purpose of this questionnaire was to get feedback and assessment from participants involved in the experimental procedures. Among the 30 participants, 29 participants completed the questionnaire. This included 9 of the skilled players and 20 of the beginners. The following content was based on the analysis of the results for the 29. Post-experimental questionnaire results for skilled players are shown in Figure 4.3.

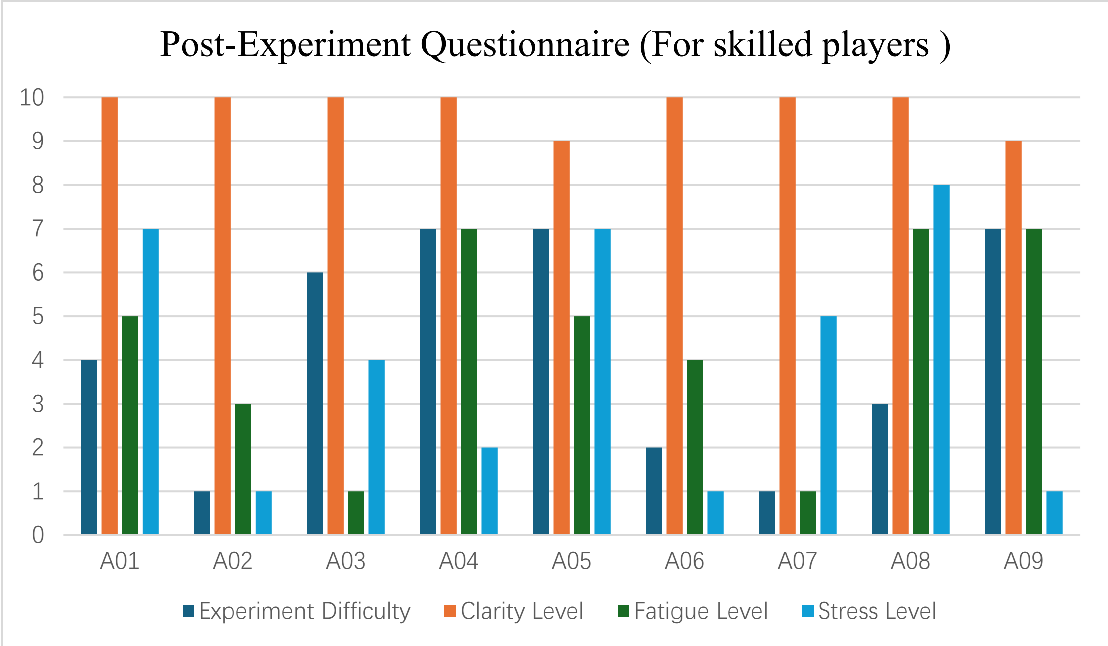

Figure 4.3 Result of post-experiment questionnaire for skilled players

As shown in Table 4.9, we calculated the average and standard deviation of skilled players. The average of the experiment difficulty was less than 5, it indicated skilled players found the tasks were not too difficult to complete. Their fatigue level and stress level were also less than 5, it indicated that they finished the task without physical or mental stress. The clarity level received the highest rating, which close to 10. It showed that the content of the experiment was well understood. The low standard deviations indicated consistent responses among skilled players, which emphasized their great adaptability.

Table 4.9 Average and standard deviation of skilled players (n=9)

	Average	Standard Deviation
Experiment Difficulty	4.22	2.59
Clarity Level	9.78	0.44
Fatigue Level	4.44	2.40
Stress Level	4.00	2.87

The results of a post-experimental questionnaire for beginners are shown in Figure 4.4 and 4.5. We have labeled the experimental group in red to distinguish it from the control group.

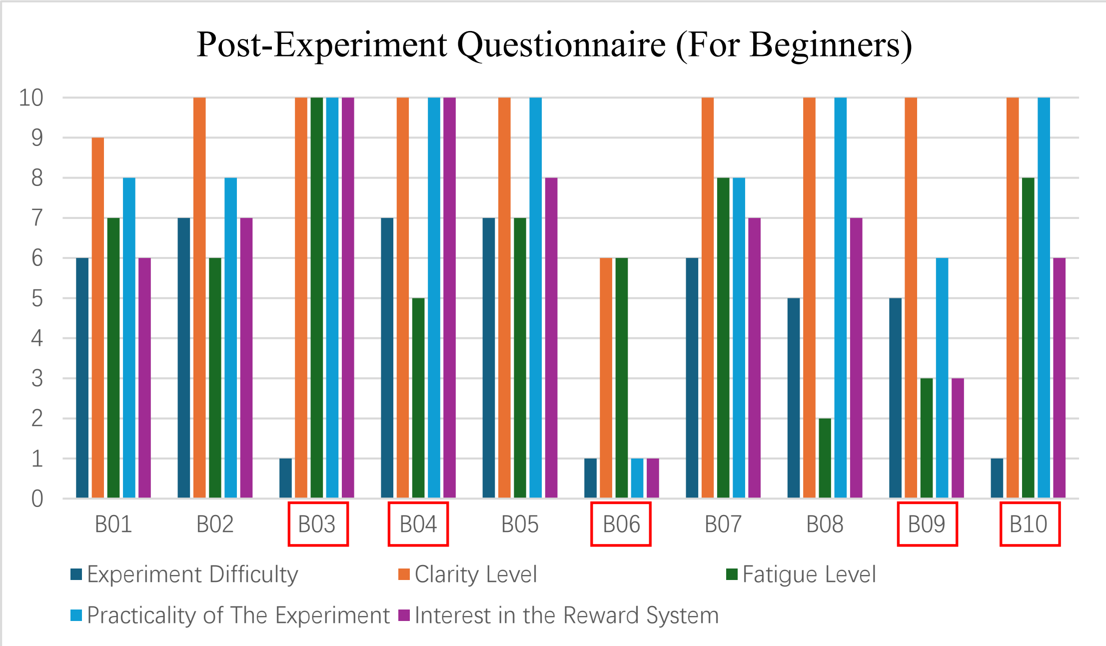

Figure 4.4 Result of post-experiment questionnaire for beginners B01-B10

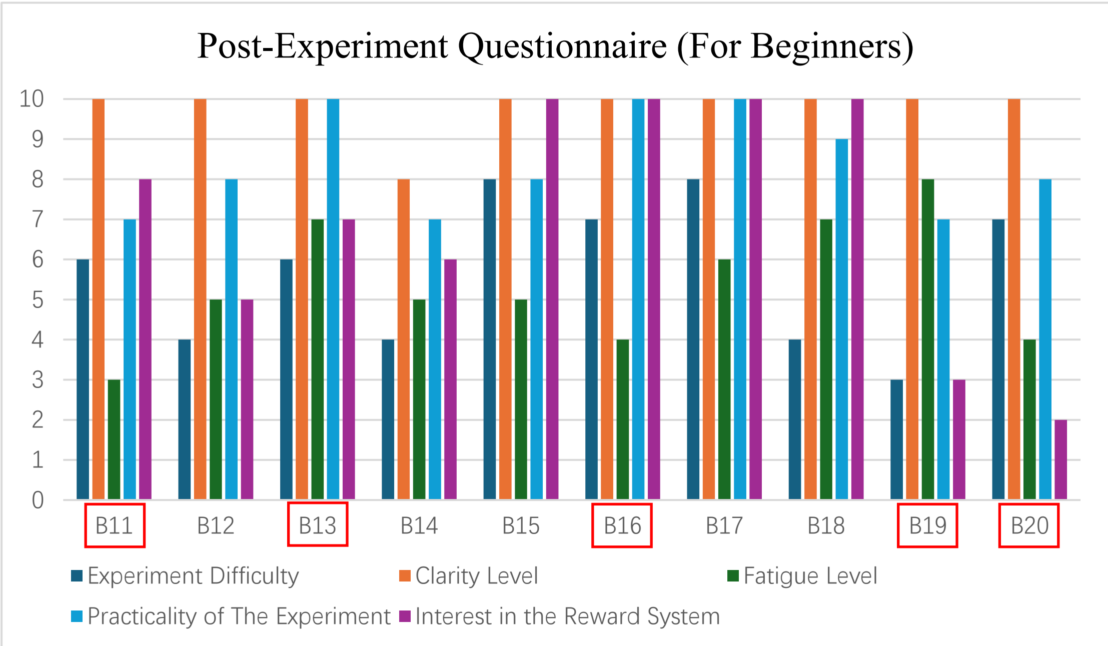

Figure 4.5 Result of post-experiment questionnaire for beginners B11-B20

In Figure 4.6 and 4.7, we presented the questionnaire results for the two groups of beginners to analyze the difference between the control group and the experimental group.

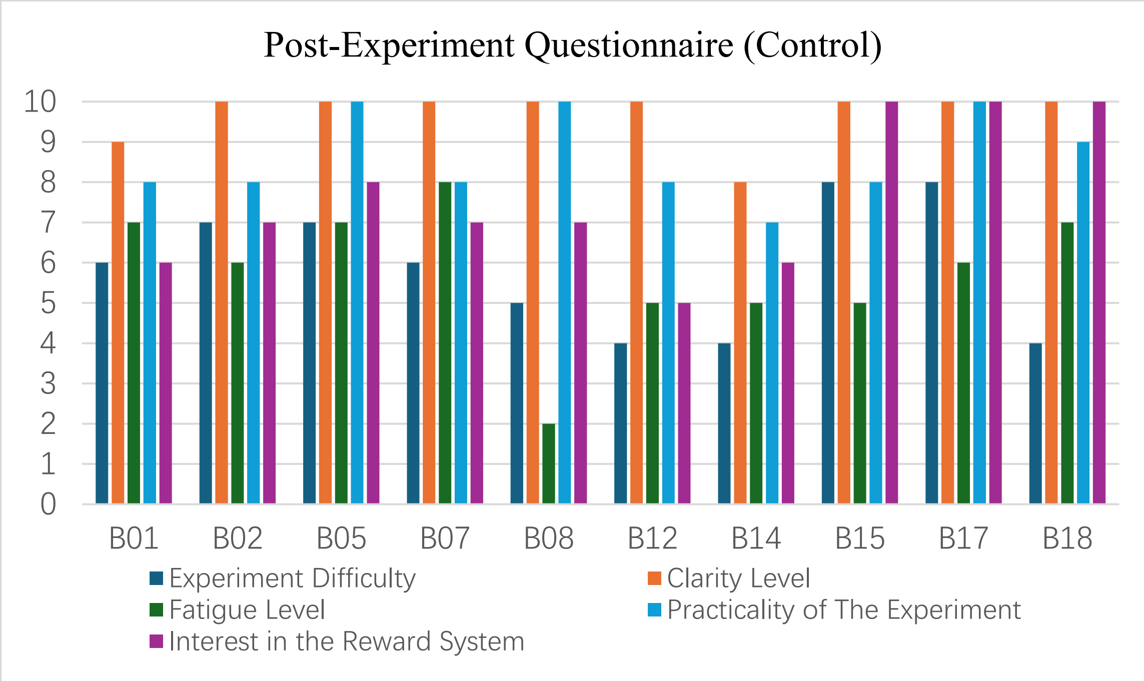

Figure 4.6 Result of post-Experiment Questionnaire of control group

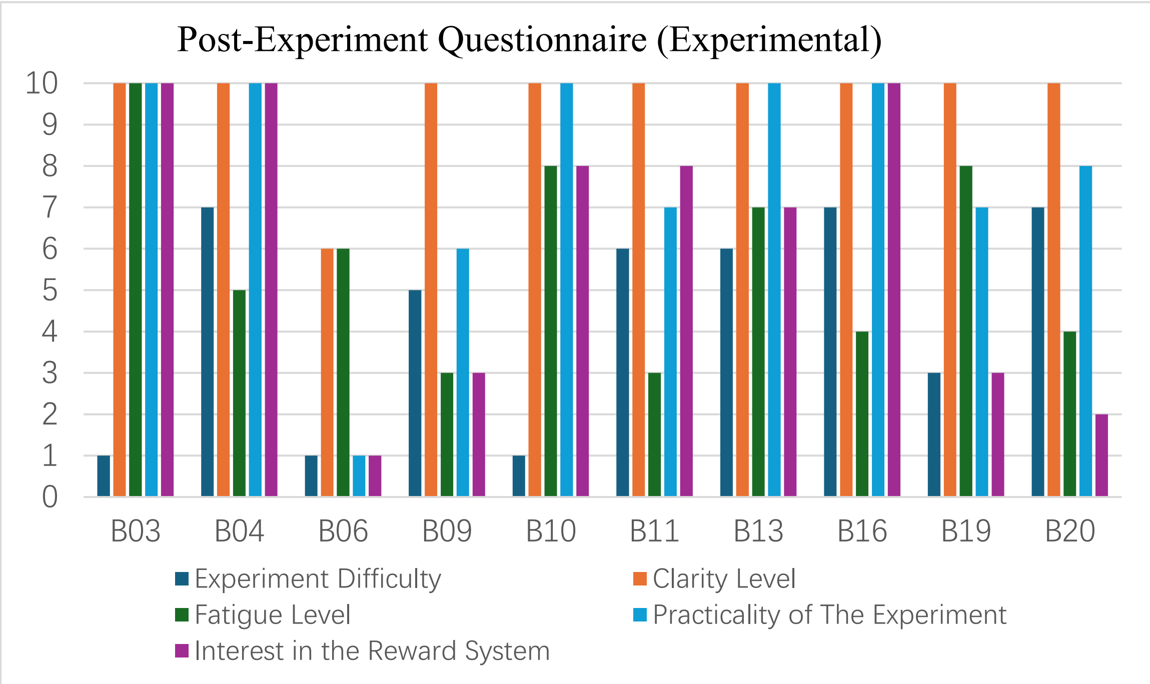

Figure 4.7 Result of post-Experiment Questionnaire of experimental group

As shown in Table 4.10 and 4.11, we also calculated the average and standard deviation of beginners. Compared to the control group and the experimental group of beginners, their average was relatively close, with only a little difference in experimental difficulty and interest in reward system. At the same time , the standard deviation of the control group was lower than the experimental group, which indicated the control group had centralized ratings than the experimental group. We used the Wilcoxon rank-sum test to analysis whether there was a significant difference between the two groups.

Table 4.10 Average and standard deviation of control group's beginners (n=10)

	Average	Standard Deviation
Experiment Difficulty	5.90	1.60
Clarity Level	9.70	0.67
Fatigue Level	5.80	1.69
Practicality	8.60	1.07
Interest in Reward System	7.60	1.84

Table 4.11 Average and standard deviation of experimental group's beginners (n=10)

	Average	Standard Deviation
Experiment Difficulty	4.40	2.63
Clarity Level	9.60	1.26
Fatigue Level	5.80	2.39
Practicality	7.90	2.88
Interest in Reward System	6.00	3.53

We also used the Wilcoxon rank-sum test to analysis whether there was a significant difference between the two groups. As shown in Table 4.12, since the P-values were all larger than 0.05, it indicated that there is no significant difference between the two groups. Therefore, the difference in average and standard deviation may be due to individual data (B06).

Table 4.12 Results of Wilcoxon Rank-Sum Test for two groups' beginners

	Statistic	P-value
Experiment Difficulty	65.5	0.250
Clarity Level	46.0	0.670
Fatigue Level	52.0	0.909
Practicality of The Experiment	59.0	0.490
Interest in Reward System	57.0	0.616

Through the statistics of the questionnaire, we concluded that the clarity and difficulty of the experiment were well designed, and both skilled and beginners were able to complete the experiment. At the same time, the fatigue and stress of this experiment were properly controlled, so that both beginners and skilled players had a good experimental experience. In addition, the reward subsystem of this experiment played a significant role in the motivation of beginners. Based on the feedback from some experimenters, we would like to offer a tiered difficulty design for beginners in future experiments, such as adding more basic tasks, especially for female beginners to start training from a position closer to the basket, to avoid bad shooting performance due to the lack of strength.

4.5 Discussion

The results of the experiment showed that a combined frontal and lateral angle analysis significantly improved the three-point shooting performance of beginners compared to the traditional lateral analysis.

1. Advantages of combination perspective analysis

Lateral only perspective analyses revealed key issues, such as the beginner B16's elbow angle during the first group of three-points shots had a big difference from the elbow angle of her target A03, which are often overlooked in purely lateral assessments. By combination of perspective analysis, beginners' shortcomings would not be ignored on both frontal and lateral perspectives.

2. Effectiveness of the matching subsystem:

By using physical characteristics to match the beginners and the skilled players, every beginner finds the most suitable training target for themselves. This effectively avoids the influence of differences in physical characteristics on training results.

3. Sample size limitations

Although the results showed significant improvement, the sample size of this experiment is a limitation. Therefore, more beginners should be recruited to participate in the experiment in the future.

4. Design for female beginners

Female beginners were limited by their strength and did not make three-point shots but showed significant improvement in shooting distance. By including the restricted area, their progress could be more accurately assessed. Future research could improve training methods to give female beginners a closer starting position.

5. Influence of the reward subsystem

The reward subsystem was effective in motivating beginners and increasing participation and effort. However, feedback suggested the introduction of tiered challenges to better accommodate different skill levels. This could make the reward subsystem more useful and personalized.

6. Limitations of skilled players

All skilled players in this study were male, which limits the gender diversity of the matching system. In addition, the training sessions were short and focused on specific phases of the shooting motion, in the future, we aim to explore long-term effects and full-motion improvements.

Chapter 5 Conclusion and Future Works

5.1 Conclusion

In this research, we developed a system to help beginners train for three-point shots by focusing on both frontal and lateral perspectives by improve the joint angles to improve the shooting percentage. We found that analyzing the shooting motion through both frontal and lateral perspectives was more effective to help beginners improve their three-point shooting percentage than the traditional way of analyzing the shooting motion from the lateral only. To test this conclusion, we conducted a comparison test between the two groups. The experimental results showed that analyzing the shooting motion from both frontal and lateral perspectives was significantly more effective in improving the three-point shooting percentage of beginners than the traditional analysis from the lateral only. This result shows advantages of combining both frontal and lateral perspectives in training three-point shooting. Section 1.2 describes the four main research questions. The following conclusions were drawn from this research:

Research Question 1: How to match a beginner with a suitable training target?

Based on this system, beginners and skilled players are matched with different weights based on physical characteristics such as gender, height, weight, left and right-hand habits. The skilled players with the closest physical characteristics will be considered as a suitable learning partner for beginners.

Research Question 2: How to accurately identify the shortcomings of beginners' shooting motions?

Based on this system, the joint angle of a certain shooting key frame of a beginner is calculated, and the result of the calculation is compared with the angle of the skilled players corresponding to the beginner, it effectively makes beginners realize their own shortcomings.

Research Question 3: How to improve the training motivation of beginners?

Based on this system, beginners can get points by improving their joint angles and make shots, and they can use the better-quality basketball according to the points they get. The motivation for beginners training for the three-point shot had been improved.

Research Question 4: What is the difference in the effect of analyzing the shooting motions from both frontal and lateral perspectives compared to analyzing the motions only from the lateral perspective?

Through the results of the experiment, we concluded that in the traditional way of analyzing only the lateral perspectives motion, the frontal perspectives motion is seriously neglected. By combining the frontal and lateral perspectives, these problems can be effectively solved, which will help improve the three-point shooting percentage of beginners.

5.2 Future Works

From the conclusion, future works should be focus on the increasing of the three-point shooting percentage of beginners after a long period of training. It should also add more technical motions, such two-point shots or free throw to determine the system's versatility and applicability in basketball.

In the current system, the shooting angle is calculated by uploading a keyframes. In the future, we will consider adding video analysis. For example, importing the complete shooting video of beginners, in which the shooting angles of the knee, elbow and shoulder joints can be displayed in real time, it can be more intuitive to observe the changes of the shooting motions during the whole shooting process, and provides the possibility to research the shooting motions in moving and confrontation.

In addition, the system needs to enrich the database of skilled players. The 10 skilled players selected for this research were all male skilled players, although we realized that there are significant differences in shooting motions and strength levels between male and female, and we gave the highest weight to gender in the matching subsystem. Unfortunately, we were unable to find any female skilled player. Therefore, we will focus on finding female skilled players in the future. We also expect to develop better training methods for female beginners to minimize the influence of strength.

Acknowledgement

First and foremost, I would like to express my deepest gratitude to my professor, Prof. Shinobu Hasegawa. As the first student to conduct sports-related research in our lab, I truly appreciate his respect for my academic interests and his unwavering support for my research direction. Throughout my two years at JAIST, he has always been patient, providing insightful guidance and invaluable expertise. Whenever I encountered challenges in my research, he offered inspiring suggestions that illuminated the path forward. His mentorship not only helped me overcome difficulties but also shaped me into a more capable and independent researcher.

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Furthermore, I am deeply grateful to all the members from JAIST International Basketball Club, as well as all the skilled players and beginners who participated in my experiment. Their cooperation provided essential data for my research. I especially admire the effort of the beginners—despite the challenges of making three-point shots, they remained committed and gave their best in every attempt.

Last but certainly not least, I would like to express my heartfelt appreciation to my parents for their financial and emotional support. Their encouragement kept me going through difficult times, helping me navigate moments of anxiety and self-doubt. Their belief in me has always been a source of strength and hope.

As I conclude this thesis, I would like to remind myself of the motto of NBA Spurs legend Tim Duncan:

"Good, better, best, never let it rest. Until your good is better and your better is best."

Publications

Lehui Lin, Wen Gu, Koichi Ota, Prarinya Siritanawan, Shinobu Hasegawa, “A Training and Support System for Three-Point Shooting for Basketball Beginners,” Research Report in Japanese Society for Information and Systems in Education.(2025 in press)

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Appendix

Consent Form

Japan Advanced Institute of Science and Technology
Affiliation: Center for Innovative Distance Education and Research
Research Supervisor: Professor Shinobu Hasegawa

I received a detailed explanation from presenter LIN Lehui on “A Training and Support System for Three-Point Shooting for Basketball Beginners”. The explanation took place at gymnasiums of JAIST, accompanied by instructional materials. I have understood the experiment's purpose, methodology, personal information protection measures, and safety management conlateralrations. I willingly consent to provide the requested personal information, data, and any related information for the experiment.

Items explained and understood.

(Please indicate with a check mark (✓) on the left lateral of the items you have understood in the consent form, and indicate with a cross mark (×) on the left lateral of the items you have not understood.)

1 Outline of the experimental plan:

（ ）・Purpose and significance of the experiment

（ ）・Information and data to be provided

2 Personal Information Protection:

（ ）・Collection of personal information is necessary in accordance with the purpose and experimental plan.

（ ）・Methods for anonymizing the provided data, etc.

（ ）・Proper storage and management of data

3 Intrusion and security management:

（ ）・Expected discomfort, burden, etc.

4 Informed consent:

( ) ・Participation in the experimental plan is voluntary.

( ) ・There will be no adverse consequences if you won't join this experiment.

( ) ・There will be no adverse consequences if the consent is withdrawn.

( ) ・If consent is withdrawn, any provided data or materials will be discarded.

( ) ・There will be no adverse consequences if you withdraw your consent.

( ) ・Provided data will be discarded upon withdrawal of consent.

( ) ・Collected data will not be shared with others without the individual's consent.

( ) ・Plans for presenting the experimental results include conference presentations and publication of papers.

( ) ・Payment (or non-payment) of compensation for participating in the research plan.

Year Month Day

Name (Signature) ________________

Contact (Email Address) ________________

Questionnaire 1

Pre-experimental questionnaire

Experimenter No.__________

１、Personal Information：

① Gender：____

② Age：____

③ Height ：____

④ Weight：____

⑤ Shooting motion：____

２、Basketball experience: (If you have)

⑥ Years of experience：_____________________________________

⑦ Record of three-point shots：_______________________________

Questionnaire 2

Post-experimental questionnaire (for skilled players)

Experimenter No___________

(i)Difficulty of the experiment

Very easy | Very difficult

1	2	3	4	5	6	7	8	9	10

(ii)Clarity of experimental content

Very unclear | Very clear

1	2	3	4	5	6	7	8	9	10

(iii)Fatigue felt after the experiment

Very relaxed | Very tired

1	2	3	4	5	6	7	8	9	10

(iv)Degree of stress felt as a learning target

Not stressful | Very stressful

1	2	3	4	5	6	7	8	9	10

(v)If you have any other suggestions or comments, please tell us.

____

____

Questionnaire 3

Post-experiment questionnaire (for beginners)

Experimenter No __________

(i)Difficulty of the experiment

Very easy　　　　　　　　　　　　　　　　　　　　　　Very difficult

1	2	3	4	5	6	7	8	9	10

(ii)Clarity of experimental content

Very unclear　　　　　　　　　　　　　　　　　　　　　　Very clear

1	2	3	4	5	6	7	8	9	10

(iii)Fatigue felt after the experiment

Very relaxed　　　　　　　　　　　　　　　　　　　　　　Very tired

1	2	3	4	5	6	7	8	9	10

(iv)The utility of this experiment in learning three-point shooting

useless　　　　　　　　　　　　　　　　　　　　　　Very useful

1	2	3	4	5	6	7	8	9	10

(v)Interests of the reward system

Bored　　　　　　　　　　　　　　　　　　　　　　Very interested

1	2	3	4	5	6	7	8	9	10

(vi)If you have any other suggestions or comments, please tell us.

____

____

____