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Technical analysis of basketball players' shooting movements through video images

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ABSTRACT

Background: With the increase in basketball competition intensity, video image analysis-based methods have been increasingly applied to improve the technical level of basketball players.

Methods: Taking the example of one-handed set shoulder shooting (the basketball player spreads legs apart at shoulder width, holds the ball over the right shoulder, extends the right hand along with lower body movement, and releases the ball softly using fingers), this study compared the technical differences between 20 level 2 basketball players (level 2 group) and 20 basketball specialized students (specialized group) by capturing video images using a high-speed camera and conducting independent sample t-tests.

Results: The level 2 group had a significantly higher shooting percentage than the specialized group ($p=0.005$). Additionally, the level 2 group had shorter dribbling time and longer shooting time compared to the specialized group ($p=0.032$; $p=0.021$). The amplitude of variation in the knee, hip, and elbow joints was significantly greater than that of the specialized group ($p=0.008/0.016/0.031$). The flexion angles of the index finger and middle finger after striking in the level 2 group were significantly higher than those of the specialized group ($p=0.021/0.036$). The level 2 group also had a smaller striking angle and a larger striking height and speed than the specialized group ($p=0.001$; $p=0.005/0.006$).

Conclusion: Athletes of different levels show differences in phase duration and joint angles when performing one-handed set shoulder shooting, providing a basis for athletes' training.

1. Introduction

This chapter provides a brief introduction to the background and existing literature of the research and analyzes the shortcomings of current studies as well as the contributions of this paper.

Basketball is a highly intense and competitive sport that combines athleticism with entertainment [1]. It enjoys immense popularity [2] and requires athletes to possess high speed, strength, and other physical attributes [3]. Shooting plays a crucial role in scoring [4], directly impacting the final outcome of the game. Both teams strive for more shooting opportunities during the game while also aiming for higher shooting percentages [5]. By analyzing the shooting techniques of basketball players, coaches can gain a better understanding of the factors that influence shooting percentages and provide more effective guidance during training [6]. With the advancement of technology, athletes' performance is increasingly quantified through numerical data [7], and video-based motion analysis methods are being applied in an expanding range of sports fields [8], such as football and badminton games. Those methods have been proven to be reliable in sports analysis. Villa et al. [9] conducted an analysis of videos of 134 cases of anterior cruciate ligament (ACL) injuries in professional male soccer players, revealing that 88% of ACL injuries occurred without direct knee joint contact. Vazini Taher et al. [10] conducted a study involving 20 professional high jump athletes. They used cameras to record videos and analyzed the effects of vertical and horizontal plyometric training programs on the athletes' explosive power. The results showed improvements in sprinting and vertical jumping abilities in the experimental group, indicating that this training program is effective in enhancing explosive power. Fong et al. [11] conducted an analysis on acute lateral ankle sprains during a badminton match by synchronizing four camera views into 3D animation software. The research revealed that at 0.12 s after the foot touched the ground, the ankle joint exhibited maximum varus, dorsiflexion, and internal rotating angular velocities of 1262°/s, 961°/s, and 677°/s respectively. Hanzlíková et al. [12] conducted an

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analysis of different landing actions in jumping. They collected data through a 3D infrared camera system and an inertial measuring unit and found that landing by rotational single-leg jump was the most challenging, which also posed a greater risk to the hands. It can be observed that motion analysis methods based on video images have been reliably applied, thus making it feasible to use this approach for technical analysis of basketball shooting movements. Currently, traditional teaching and learning methods are mostly employed in training basketball players, where athletes practice their movements under the guidance of coaches. In this process, coaches need to invest a great deal of effort and subjectivity is heavily involved in providing movement instructions. As a result, coaches' understanding of athletes' technical proficiency tends to be rough and general, making it difficult to obtain precise sports data for analysis. Although there have been some studies on shooting techniques in current basketball research, there is still relatively little focus on the study of the one-handed set shoulder shooting motion due to its diversity. As an important skill in shooting, it is worth coaches' attention to exploring whether there is a correlation between the level of one-handed set shoulder shooting motion and athletes' proficiency, as well as the differences among athletes of different levels when performing this motion as it will be beneficial in providing more targeted guidance for practicing this motion. To better understand the technical differences between athletes of different levels, the article conducted an analysis of video images to study single-handed set shoulder shots and compared athletes at different skill levels. It provides references for improving shooting percentages and also serves as a basis for athletes' daily training. Moreover, this study helps coaches to better understand the differences in technique execution among athletes of different levels, enabling them to develop more targeted corrective training programs and improve the athletes' technical proficiency. It also enhances the efficiency of daily training for athletes and demonstrates that video imagery serves as a more objective analysis tool, providing precise data for coaches, athletes, and researchers. Therefore, this method can be applied to other technical movements and sports disciplines, improving technical skills and athletic performance.

2. Research subjects and methods

This section offers a comprehensive overview of the research topic and provides detailed explanations of the research methods, encompassing both experimental procedures and data processing techniques.

2.1. Research subjects

A study was conducted to compare the shooting actions of 40 basketball players at different skill levels from Chongqing Vocational and Technical University of Mechatronics. Twenty players were level 2 athletes with high skill levels and were classified as the level 2 group. The other twenty players were basketball-specialized students with lower skill levels and were classified as the specialized group. They were all males. Prior to the experiment, these students refrained from vigorous exercise for 24 hours. They all comprehended the purpose and significance of the experiment and signed informed consent forms.

2.2. Methods

The experiment was conducted in the indoor basketball court on campus, with natural lighting and an indoor temperature of 23 °C at school. All subjects dressed uniformly and used the FIBA standard size 7 basketball. The experimental action was shooting from shoulder level while standing in place.

① Dribbling: The student stood with two legs open and shoulder-width apart. The right hand held the ball at shoulder level, with the wrist tilted back, fingers naturally spread out, and the palm upwards. The center of gravity of the ball was placed between the index finger and the middle finger. The left hand supported the ball while both legs were slightly bent, and eyes focused on the front edge of the basket.

② Shot: The right hand was fully extended along with the lower body's pedaling and stretching, while the left hand was separated from the ball. The right wrist flexed forward, gently flicking the ball with soft fingers. After the shot, the body stretched out, palm faced downwards, and arms relaxed.

A high-speed Casio camera from Japan was used to capture the shooting action. The camera was positioned at a height of 1.25 m and had a horizontal distance of 10 m from the athlete and a frame rate of 120 f/s, as shown in Fig. 1.

The specific experimental procedure is shown below.

① The basic information of athletes was collected. The experimental venue was set up. The players were arranged for routine warm-ups.

② Each athlete completed ten single-handed set shoulder shots while experimenters recorded the number of goals achieved. Taking one of the players as an example, Fig. 2 shows the video images captured by the camera.

③ Markers were pasted on the body of the player. Based on the technical characteristics of single-handed set shoulder shooting, combined with existing research and expert opinions, the position for attaching markers was determined. The positions of the markers are shown in Fig. 3 and Table 2.

④ The camera was turned on and operated without moving and shielding. Each player performed five single-handed set shoulder shots, and the most standard and clean shot out of the five attempts was selected for technical analysis.

2.3. Statistical analysis of data

In Simi Motion software [13], the video images captured by the camera were processed. During the analysis, the Hanavan human body model was used. Operations such as cropping and synthesis were performed on the video. Then, the built-in data parsing system obtained

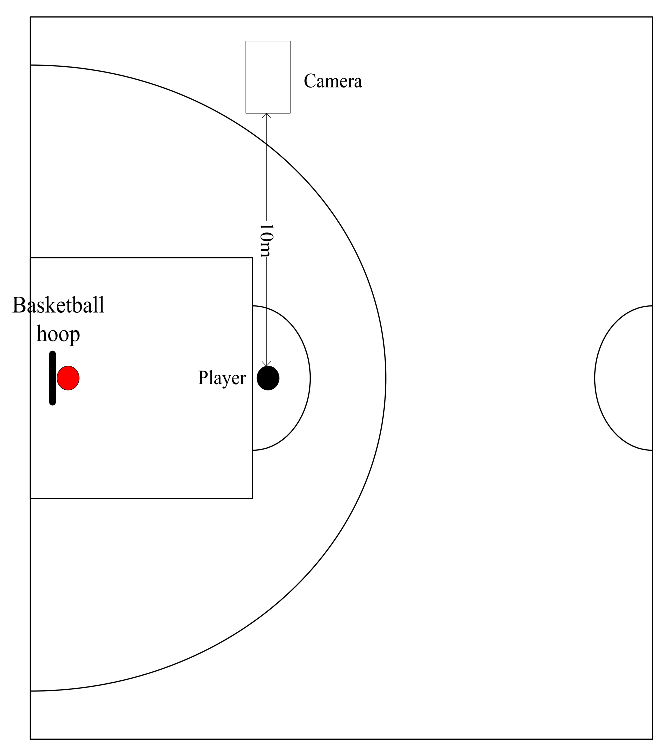

Fig. 1. Experimental venue

Fig. 2. An example of single-handed set shoulder shooting

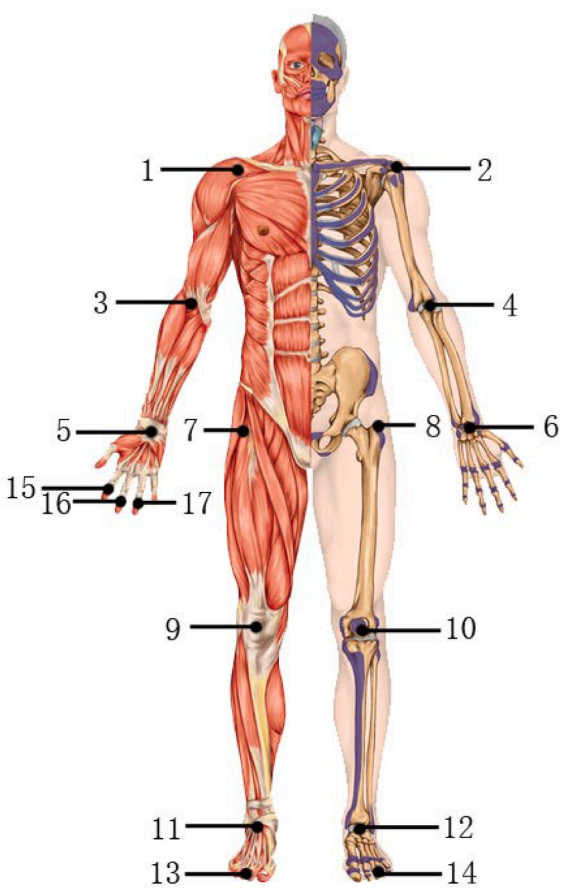

Fig. 3. Positions of markers

various indicators such as joint angles, body center of mass height, and velocity. The data was organized in Excel and recorded in the form of mean±standard deviation ($\bar{x} \pm sd$). Statistical analyses were conducted using SPSS 21.0 software. The Shapiro-Wilk test was used to determine if a sample followed a normal distribution. For samples that followed a normal distribution, an independent sample t-test was performed to compare the technical differences in shooting actions between the two groups. The significance level was set at 0.05. If $p < 0.05$ in comparing between the two groups, it means a significant difference. The effect size intensity was computed according to the ES guidelines provided by Cohen, and small, medium, and large Cohen's d coefficients were 0.2, 0.5, and 0.8, respectively [14]. Finally, charts were created using Excel software to present the results.

3. Result analysis

In this section, the results of the experiment were analyzed, and the differences between the two groups of data were compared using P values and Cohen's d values.

Firstly, the shooting percentage is shown in Table 3.

According to Table 3, out of the 100 shots, the level 2 group achieved 87 successful shots, while the specialized group only achieved 66. The number of goals of the level 2 group was significantly higher than that of the specialized group ($p<0.05$). The two groups had shooting percentages of 87% and 66%, respectively, with the level 2 group demonstrating a clear advantage over the specialized group ($p<0.05$). In terms of effect size, Cohen's d values for the total number of goals and shooting percentage were 1.21 and 1.22, respectively, indicating large effect sizes. The results revealed significant differences in shooting percentages among basketball players of different skill levels.

The time spent in the dribbling and shooting stages was compared (Table 4).

From Table 4, it can be observed that the level 2 group had a shorter dribbling time than the specialized group (0.68±0.04 s vs. 0.73±0.05 s) ($p<0.05$). Additionally, in the shooting stage, the level 2 group spent a longer time in shooting compared to the specialized group (0.36±0.05 s vs. 0.29±0.06 s) ($p<0.05$). In terms of effect size, Cohen's d values for ball dribbling time and shooting time were 0.25 and 0.26 respectively, indicating small effect sizes and suggesting that there was only a minor difference between the two groups in terms of ball dribbling and shooting stages. From the perspective of the game process, shorter dribbling time was advantageous for quickly getting rid of opponents and completing shots, while longer shooting time helps players release the ball before reaching the highest point of their center of gravity, thus achieving better shooting results.

The magnitude of changes in joint angles was compared between the two groups (Table 5).

According to Table 5, significant differences were observed between the two groups in terms of knee, hip, and elbow joint comparisons. Specifically, the level 2 group showed a variation amplitude of 60.33 ±2.12° in the knee joint, while the specialized group was 56.45±3.07°; in terms of the hip joint, the level 2 group was 15.27±1.56°, and the specialized group was 13.84±1.12°; in terms of the elbow joint, the level 2 group was 62.64±3.25°, and the specialized group was 55.76±2.87°, indicating an insignificant difference. Both groups showed a large effect size in the variation amplitude of the knee, hip, and elbow joint angles, indicating significant differences. During shooting, the level 2 group exhibited greater changes in knee, hip, and elbow angles, indicating a more complete extension of their bodies and achieving better shooting speed. Therefore, they also had superior shooting results.

The flexion angles of fingers after shooting were compared between the two groups, and the results are presented in Fig. 4 and Table 6.

From Fig. 4, it can be observed that there were some differences in the flexion angles of the index, middle, and ring fingers between the two groups after shooting. According to Table 6, the level 2 group had a flexion angle of 150.87±18.64° for the index finger, while the specialized training group had a flexion angle of 138.25±20.33°; for the middle finger, the second-level group had a flexion angle of 152.31±19.67° and the specialized group had a flexion angle of 142.72±19.86°; for the ring finger, the level 2 group had a flexion angle of 157.64±12.23° and the specialized group had a flexion angle of 156.88±11.57°. In comparison, the level 2 group had significantly larger flexion angles in the index and middle fingers ($p < 0.05$) and a slightly larger flexion angle in the ring finger ($p > 0.05$) compared to the specialized group. The effect sizes for the flexion angles of the index and middle fingers after shooting in both groups were large (Cohen's d values were 1.78 and 1.06 respectively), with significant differences. These results showed that in the process of completing the shooting action, the downward pressure of the index and middle fingers in the level 2 group was relatively small, with gentle and passive force exertion, and the shot was released smoothly, resulting in better shooting effectiveness.

The shooting angle, height, and speed were compared between the two groups, and the results are displayed in Fig. 5 and Table 7.

Fig. 5 shows that there were difference in shooting angle, height, and speed between the two groups. According to Table 6, firstly, in terms of shooting angle, the level 2 group was 55.64±1.27°, and the specialized group was 62.37±1.25°; in terms of shooting height, the level 2 group was 3.36±0.03 m and the specialized training group was 3.05±0.02 m; in terms of shooting speed, the level 2 group was 5.47±0.76 m/s and the specialized group was 5.13±0.68 m/s. By comparison, it can be observed that the shooting angle of the level 2 group was significantly smaller than that of the specialized group, while both the shooting height and speed were noticeably greater in comparison to those of the specialized group ($p<0.05$). In terms of effect size, both groups showed significant differences in shooting angle, height, and speed. In conclusion, when they shot, the members of the level 2 group had a higher shooting height and a reduced shooting angle. A faster shooting also indicated that the players performed their movements more effectively, thereby enhancing shooting percentages.

4. Discussion

In this section, the experimental results were discussed and compared briefly with existing research. The limitations of the study and future directions for further work were also analyzed.

4.1. Analysis of time consumption

In basketball, scoring is achieved by creating more shooting opportunities and achieving a higher shooting percentage [15]. Therefore, mastering the shooting technique is crucial. Currently, there has been some research on basketball shooting techniques. Fan et al. [16] conducted a study on the recognition of basketball shooting postures by integrating data from ten sensors. Based on the identification using the squeezed convolutional gated attention-based deep learning model, they found that the average accuracy of this method reached 98.79%. Amaro et al. [17] explored the effect of athletes' visual behavior on shooting positions and angles. Through comparisons among 18 basketball players, they found statistically significant differences in the number and total duration of fixations and shooting accuracy. Kuhlman et al. [18] utilized data from wearable systems, employed a secondary support vector machine classifier to classify four distinct shooting styles accurately, and obtained an accuracy of 85%. Suzuki et al. [19] investigated the correlation between basketball shooting distance and release parameters. They discovered that when positioned at distances of either 5.75 m or 6.25 m from the basket, it is essential to reduce the release angle while simultaneously increasing the release velocity. Sirnik et al. [20] examined how visual attention affects shooting performance and pointed out that quiet eye training can enhance shooting efficiency. The single-handed set shoulder shot is a fundamental shooting motion, especially widely used in free throws. Although the shooting percentage can be influenced by factors such as psychological state, fatigue level, and physical strength [21,22], it cannot be achieved without mastering the correct and reliable technical essentials. By analyzing the technical differences in single-handed set shoulder shooting among athletes of different levels, we can gain a better understanding of how to achieve higher shooting percentages.

From comparing the time taken for dribbling and shooting between the two groups, it can be observed that both groups took longer to possess the ball than to shoot. When performing single-handed set

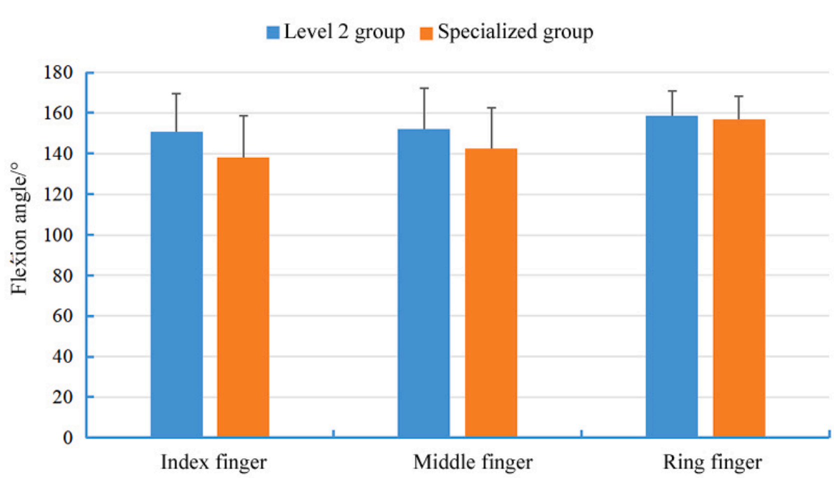

Fig. 4. Comparison of flexion angles between fingers after shooting.

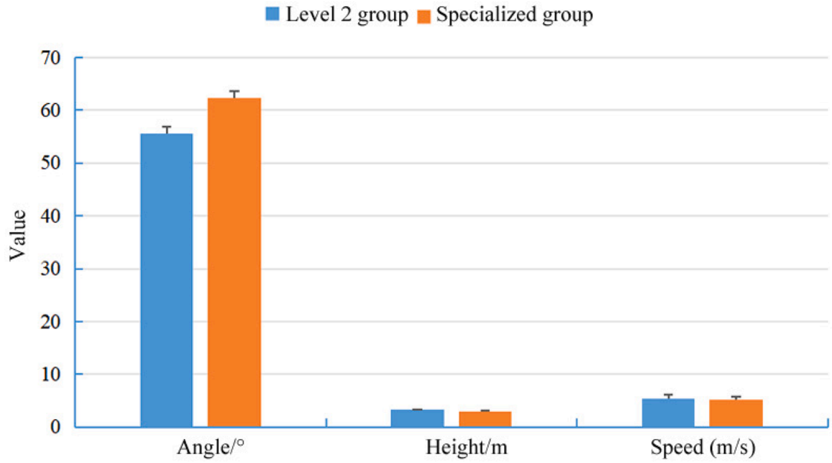

Fig. 5. Comparison of shooting angles, height, and speed between the two groups

shoulder shots, athletes generated upward force by fully raising the ball above their heads. From the comparison of the two groups, it can be observed that the level 2 group had a shorter dribbling time ($p=0.008$, Cohen's $d=1.21$) and longer shooting time ($p=0.005$, Cohen's $d=1.22$) compared to the specialized group ($p<0.05$). This suggested that individuals in the specialized group tended to have their body center of gravity in a falling state when shooting, which can easily result in mistiming the shooting and make them more vulnerable to being blocked by opponents due to delayed shots. This result is similar to the finding of Shigematsu et al. [23], i.e., a shorter pre-shot time can lead to a higher free throw shooting percentage. In summary, a shorter ball dribbling time is more advantageous for achieving better shooting accuracy.

4.2. Joint angle analysis

Jumping plays a significant role in the shooting. It is highlighted by the research conducted by Pomohaci et al. [24] that jumping ability is a primary and fundamental skill for basketball players. From the comparison of changes in joint angles between the two groups, it can be observed that the level 2 group exhibited significantly greater variations in knee, hip, and elbow joints compared to the specialized group ($p=0.008/0.016/0.031$, Cohen's $d=2.12/1.34/1.07$). In the process of shooting, the flexion of the knee joint helps elongate muscle groups, store elastic potential energy, and provide power for extending the knee joint, thereby achieving better pedaling and stretching effects. The flexion of the hip joint also plays a similar role. The body can swing upward by flexing the knees and hips, driving the center of gravity to rise and increasing shooting height. Additionally, a greater variation in the elbow joint angle is beneficial for generating more shooting power and achieving better shooting results.

During the shooting motion, the main force is generated by the index finger, middle finger, and ring finger. There was a significant difference in flexion angle between the level 2 and specialized groups for both index and middle fingers ($p=0.021/0.036$, Cohen's $d=1.78/1.06$). The strength of fingers during shooting comes from transmitting arm and wrist power rather than active force generated by the fingers. From the results in Table 5, it can be observed that the level 2 group exhibited a larger flexion angle of their fingers, whereas the specialized group demonstrated a smaller flexion angle. This implies that the specialized group may rely on individual finger force to execute shooting and throwing actions, which can result in an inconsistent shooting process and impact ball flight stability. Consequently, the shooting percentage of the specialized group is lower than that of the secondary group. In this process, the level 2 group connected the force of lower limb extension to the arms, wrists, and fingers, making the ball more stable when released and ensuring overall coordination.

4.3. Analysis of shooting percentage

The higher shooting height allows the player to be closer to the basket, so athletes can increase the ball's height without adjusting the shooting angle, resulting in a more fluid motion. In addition, a higher shooting height results in a shorter distance for the ball to travel through the air and faster shooting. In conclusion, a smaller angle, greater height, and faster speed at the time of shooting are more advantageous for athletes to coordinate and execute their actions smoothly. This also increases the likelihood of overcoming defensive interference from opponents, thus leading to higher shooting percentages. The result is consistent with the finding of Stojanovi et al. [25], i.e., athletes with weaker shooting skills have significantly lower shooting angles. Caseiro et al. [26] also found in their study that jumping higher and shooting near the peak of the jump can lead to better shooting performance. Smajla et al. [27] discovered through a comparison of basketball players' elbow extensor and wrist flexor muscles that muscular strength plays an important role in shooting ability. From the current research and the results of this study, it can be concluded that angles, heights, and speeds at release are all aspects that athletes need to improve through continuous training in order to achieve higher shooting accuracy.

4.4. Training suggestions and limitations of research

Based on the comprehensive experimental results, it can be observed that the assumption of this article is correct, namely, there are significant differences in data when athletes of different levels perform this movement. Based on the differences exhibited by the two groups of athletes, in order to achieve a higher shooting percentage, when performing the one-handed set shoulder shot motion, players should:

(1) release the ball in a timely manner before the body's center of gravity drops,
(2) pay attention to fully extending and generating elastic potential energy in the lower limbs,
(3) enhance training for explosive power and jumping ability in the lower limbs to achieve higher release heights,
(4) strengthen training for body coordination, focusing on coordinated force generation in all joints,
(5) pay attention to transferring power from the arms and wrists when flicking the ball,
(6) enhance muscle strength training to improve the required muscle strength during execution of movements.

In general, the method proposed in this article is effective in understanding the technical differences among basketball players of different levels. Based on video image analysis, it helps to understand the data differences when athletes of different levels perform movements, thereby improving their technical level and shooting quality. Although it cannot achieve automatic correction of movements, it provides reliable data support for coaches, athletes, and researchers. The research findings have demonstrated the reliability of video image analysis in the field of sports, providing new strong support for further application of this technology in sports. However, this study has some limitations. Due to time constraints, a small and homogeneous sample size was selected without considering other factors such as age and gender that may affect the completion of one-handed set shoulder shooting movements. Therefore, future research will expand experiments on a wider range of samples and add studies on more factors. In addition to athletic ability, diverse factors will be combined to further investigate the technical characteristics of one-handed set shoulder shooting movement in order to provide guidance for practical teaching and training.

5. Conclusions

This section provides a summary of the research content and draws conclusions.

The article compared the technical differences between basketball players of different skill levels by analyzing video images. The following results were obtained.

(1) Compared to the specialized group, the level 2 group had a shorter dribbling time and longer shooting time ($p<0.05$).
(2) Compared to the specialized group, the level 2 group showed greater changes in knee, hip, and axial joint angles ($p<0.05$).
(3) During shooting, the level 2 group exhibited significantly larger flexion angles in their index and middle fingers compared to the specialized group ($p<0.05$); however, there was no significant difference in flexion angle for their ring finger.
(4) Compared to the specialized group, the level 2 group exhibited a smaller shooting angle, higher shooting height, and faster speed ($p<0.05$).

The research findings demonstrate technical differences among players of different levels and provide valuable insights for their training. These experimental results can help enhance players' shooting percentages, (Table 1).

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CRediT authorship contribution statement

Bin Dai: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Yanan Yin:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology,

Table 1
General information of research subjects

	Level 2 group (n=20)	Specialized group (n=20)
Age/year	21.78±1.43	21.37±1.26
Height/m	1.88±8.47	1.89±7.62
Weight/kg	82.36±7.81	83.41±6.73
Training time/year	11.26±1.12	3.64±1.23
Strong hand	Right	Right

Table 2
The name of the marker positions

Serial number	Name
1	Right shoulder joint
2	Left shoulder joint
3	Right elbow joint
4	Left elbow joint
5	Right wrist joint
6	Left wrist joint
7	Right hip joint
8	Left hip joint
9	Right knee joint
10	Left knee joint
11	Right ankle joint
12	Left ankle joint
13	Right toe
14	Left toe
15	The second distal interphalangeal joint of the right hand
16	The third distal interphalangeal joint of the right hand
17	The fourth distal interphalangeal joint of the right hand

Table 3
Comparison of shooting percentages

	Level 2 group (n=20)	Specialized group (n=20)	P value	Cohen's d
Number of goals/n	87*	66	0.008	1.21
Shooting percentage/%	87*	66	0.005	1.22

Note: * indicates $P < 0.05$ compared to the specialized group.

Table 4
Comparison of dribbling and shooting time

	Level 2 group (n=20)	Specialized group (n=20)	P value	Cohen's d
Dribbling time	0.68±0.04*	0.73±0.05	0.032	0.25
Shooting time	0.36±0.05*	0.29±0.06	0.021	0.26

Note: * indicates $p < 0.05$ compared to the specialized group.

Table 5
Comparison of amplitude of variation in joint angles (unit: °)

	Level 2 group (n=20)	Specialized group (n=20)	P value	Cohen's d
Knee joint	60.33±2.12*	56.45±3.07	0.008	2.12
Hip joint	15.27±1.56*	13.84±1.12	0.016	1.34
Ankle joint	37.26±1.83	35.96±1.77	0.077	0.14
Elbow joint	62.64±3.25*	55.76±2.87	0.031	1.07

Note: * indicates $p < 0.05$ compared to the specialized group.

Table 6
Comparison of finger flexion angles after shooting (unit: °).

	Level 2 group (n=20)	Specialized group (n=20)	P value	Cohen's d
Index finger	150.87±18.64*	138.25±20.33	0.021	1.78
Middle finger	152.31±19.67*	142.72±19.86	0.036	1.06
Ring finger	158.64±12.23	156.88±11.57	0.067	0.15

Note: * indicates $p < 0.05$ compared to the specialized group.

Table 7
Comparison of shooting angle, height, and speed

	Level 2 group (n=10)	Specialized group (n=10)	P value	Cohen's d
Angle/°	55.64±1.27*	62.37±1.25	0.001	2.68
Height/m	3.36±0.03*	3.05±0.02	0.005	2.33
Speed/(m/s)	5.47±0.76*	5.13±0.68	0.006	1.36

Note: * indicates $p < 0.05$ compared to the specialized group.

Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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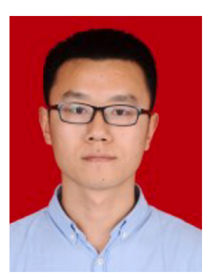

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