

## *Retraction*

# **Retracted: Recognition of Volleyball Player's Arm Motion Trajectory and Muscle Injury Mechanism Analysis Based upon Neural Network Model**

### **Journal of Healthcare Engineering**

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

### **References**

- [1] J. Zhao and Z. Li, "Recognition of Volleyball Player's Arm Motion Trajectory and Muscle Injury Mechanism Analysis Based upon Neural Network Model," *Journal of Healthcare Engineering*, vol. 2022, Article ID 8114740, 15 pages, 2022.

## Research Article

# Recognition of Volleyball Player's Arm Motion Trajectory and Muscle Injury Mechanism Analysis Based upon Neural Network Model

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At present, in sports training for volleyball, it still mainly depends on the personal experience of the coach. Training costs are high, and the quality is difficult to maintain stable. Even with the introduction of training assistance software, it is often necessary to manually enter complex data, and the research samples are mostly single individuals. Serving is one of the basic and important technical movements of volleyball, and its standardization is of great significance to the stable performance of the scene. This article proposes an analysis of the volleyball player's arm trajectory based on the background of human posture recognition and analysis, based on the neural network model. The changes in the angles of the shoulders, elbows, and wrist when serving the ball reflect the different trajectories of the arm. Experiments show that the height of the throwing arm from the ground accounts for 98% of the height. The horizontal angle of the throwing arm at the moment the ball leaves the hand is positively correlated with the throwing time and height, and the reasonable trajectory has an impact on the stability of the throwing ball. The closer the trajectory of the tossing arm is to the vertical, the more stable the tossing is.

## 1. Introduction

The article takes serving training in volleyball training as an application scenario. Based on the monocular video research method to obtain the athlete's body posture evaluation index, the volleyball player's arm trajectory is recognized. And through the comparison of shoulder and elbow angle changes, this article explores the difference of serve movement and forms the evaluation result of the training quality of serve movement. It provides a reference basis for coaches to find problems in a targeted manner. The change of the arm's trajectory during the serve has an important role in accumulating force for the next stage of explosion. Therefore, we study the running trajectory of the throwing arm to provide information for training and teaching and improve the quality of serve.

Nowadays, people's attention to sports competition, based on the in-depth analysis of big data technology, has made many scholars' more in-depth research on the

recognition and analysis of sports gestures. With the support of neural networks, the recognition and analysis of motion trajectories have new endpoints. Shu W uses an improved neural network to extract the trajectory features of the athletes in the football game video and trains the network on a large number of data objects containing similar objects, which improves the algorithm's ability of distinguishing the trajectories of the athletes. Experimental results show that the algorithm has a good effect in the field of football, with an accuracy rate of over 90% [1]. Rock climbing trajectory is the basic data for coaches to select athletes and formulate follow-up training plans. Zhang J proposed a bolt-shaped friction nanogenerator (BS-TENG), which can be used for trajectory detection during rock climbing training. The peak value of the output voltage pulse is between 4 and 7 V, which has a strong signal-to-noise ratio and anti-interference ability [2]. Based on the internal model assumptions, during the planning and execution of voluntary tracking exercises, Shevtsova et al. numerically model the motion control

process of the higher regions of the human brain. They used measures such as Kalman filter, linear quadratic estimator, and linear quadratic regulator. Based on the analysis of the tracking motion trajectory, they proposed a method to determine the activation time of the control [3]. Melo et al. accurately detect the line and ball position by applying color filters and transformations in combination with a support vector machine. They use different pictures to track the ball's position and use mathematical models to estimate the ball's trajectory and help predict the moment of contact. In this work, they applied the extended Kalman filter to reduce the measurement error and improve the detection performance by predicting the future position of the ball. The results show that this method has excellent performance and technical feasibility for deployment in low-cost embedded computers [4]. Liu et al. proposed a nonbackstepping predictive controller based on a dynamic linearized multilayer feedforward neural network (MFNN) model. This method does not require an inverse model of inherent hysteresis, and the control law can be obtained explicitly. Experimental results show that the method proposed has satisfactory tracking performance even under high-frequency reference [5]. Nikitin et al. solve the video-based face recognition problem. They proposed a new neural network model that uses a person's facial image input set to generate a compact, fixed-dimensional descriptor. These feature vectors are weighted according to their utility estimates to produce a feature representation of the image set. Experiments show that the feature aggregation method based on face quality evaluation proposed is always better than the traditional aggregation method [6]. The proposals of these theories have a more in-depth effect on the application of neural networks to a certain extent. Although it has a wider application range, they all have certain defects more or less and cannot be considered comprehensively. Moreover, the experimental process is relatively complicated, there are many calculation places, and problems such as calculation errors are prone to occur.

The innovation of this article is the gesture recognition of today's sports athletes, which is mostly group or single individual gesture recognition. This article is based on the background of deep neural network to recognize the volleyball player's arm trajectory. Through the analysis of the trajectory of the throwing arm and the angles of the shoulder and elbow joints, it draws the attention points that are more conducive to the training of volleyball players for better training [7].

## 2. Neural Network Model Based on Volleyball Arm Recognition

### 2.1. Neural Network Based on Volleyball Arm Trajectory Recognition

**2.1.1. Fully Convolutional Network.** Fully Convolutional Networks (FCN) can classify images at the pixel level, and the network structure is shown in Figure 1. Compared with the traditional convolutional neural network CNN, there is a slight difference [8]. There are two key technologies in FCN.

**2.1.2. Convolution.** The schematic diagram of the convolution is shown in Figure 2. The classic convolutional neural network CNN classification network is usually the fully connected layer at the end [9]. However, this will lose the spatial information of the feature [10, 11]. The output of the two-dimensional segmentation map required for image semantic segmentation is Mask. To obtain a two-dimensional matrix, a convolutional layer is used to replace the fully connected layer in the last layer. That is the meaning of convolution [12].

**2.1.3. Upsampling.** Upsampling is the process of generating a heat map. The specific performance is that after the network performs convolutional pooling for 5 times, the image will be reduced by a square number, such as 2, 4, and 8 times. Until the last layer is upsampled by 32 times, it is possible to obtain a picture with the same size as the original picture. Now, we need to restore the image size of the convolutional layer to the original image size. The upsampling method is used in FCN, and the specific implementation is deconvolution [13]. The extraction diagram is shown in Figure 3.

**2.2. Recurrent Neural Network.** Recurrent Neural Network (RNN for short) is a view based on the following: "human cognition is the past experience and memory." Different from general neural networks, RNN is a special neural network structure [14]. The problem with RNN and CNN is that it not only considers the input at the previous moment, but also provides the network with the "storage" function of the previous content [15]. The reason RNN is called a Recurrent Neural Network is that, in the hidden layer within the neural network of the network, no connections between neuron nodes will be replaced by links and the outputs of the previous hidden layer and the input layer together form inputs to the hidden layer.

**2.2.1. RNN Model Structure.** As shown in Figure 4, it can be seen that the RNN hierarchical structure ratio is mainly composed of the input layer, the hidden layer, and the output layer. The arrow in the "hidden layer" indicates that the data is being updated regularly [16].

This section expands the hidden layer structure diagram of the RNN as shown in Figure 4, using  $q$  as the sample input. At this time, the memory of the sample at time  $s$  is represented by  $T_s$ , so  $T_s = f(M \cdot T_{s-1} + N \cdot q_s)$ . The  $M$  table starts with the weight of the input, and  $N$  is the weight of the input during the process, and the weight of the output of the  $R$  table is used.

When  $s = 1$ , initialize  $T_0 = 0$  as the input value and  $M, N$ , and  $R$  randomly, and calculate the following equation:

$$\begin{aligned} e_1 &= Nq_1 + MT_0 \\ T_1 &= f(e_1) \\ c_1 &= y(NT_1) \end{aligned} \quad (1)$$

In the equation,  $f$  can represent multiple activation functions, such as tanh, Relu, and Sigmoid. And  $y$ , which

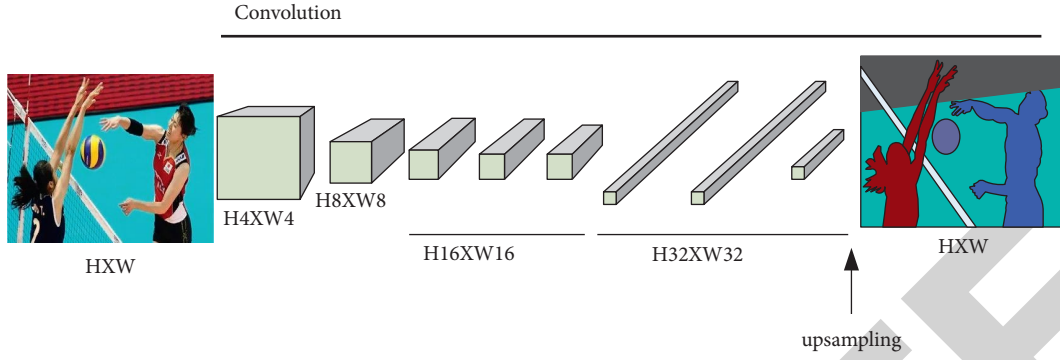


FIGURE 1: FCN network structure diagram.

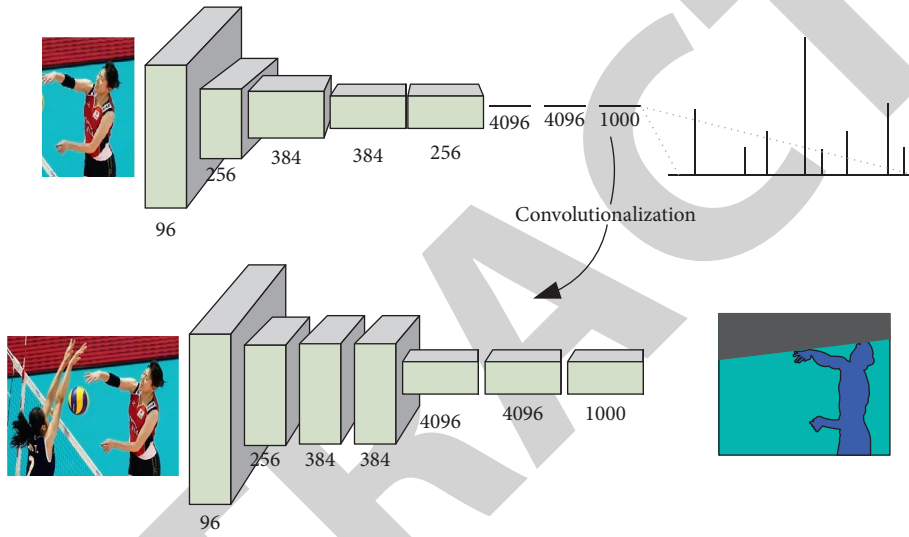


FIGURE 2: Schematic diagram of convolution.

also represents the activation function, usually only represents Softmax. As time grows, the prediction equation of the storage state of the T1 table at time 1 is as follows:

$$\begin{aligned} e_2 &= Nq_2 + MT_1, \\ T_2 &= f(e_2), \\ c_2 &= y(NT_2). \end{aligned} \quad (2)$$

As shown in Figure 5, the derivation is based on this

$$\begin{aligned} e_t &= Nq_2 + MT_{s-1}, \\ T_s &= f(e_s), \\ c_s &= y(NT_s). \end{aligned} \quad (3)$$

**2.2.2. Backpropagation of RNN.** The previous section introduced the basic method of forward propagation. This section updates the  $M$ ,  $N$ , and  $R$  weight parameters of the neural network's reverse transmission. That is, in the representation method  $H = \sum h_s$  of the output value  $c_s$  and the error value to the total error  $h_s$ , when the square loss or cross

entropy is used as the loss function, the output of each step is not only affected by the current network, but also by the influence of the network status of the upper layer, so it is also called the backpropagation of time. The error value of this transmission method is mainly updated by the gradient descent method; namely,

$$\begin{aligned} H &= \sum_s h_s, \\ \Delta N &= \frac{\alpha H}{\alpha N} = \sum_s \frac{\alpha h_s}{\alpha N}, \\ \Delta R &= \frac{\alpha H}{\alpha R} = \sum_s \frac{\alpha h_s}{\alpha R}, \\ \Delta M &= \frac{\alpha H}{\alpha M} = \sum_s \frac{\alpha h_s}{\alpha M}. \end{aligned} \quad (4)$$

Based on the parameter update method,  $M$  is updated as the sum of each bit deviation. Here, the update method of  $M$  needs to be solved first. Assuming  $s = 5$ , according to the chain derivation, it can be expressed as

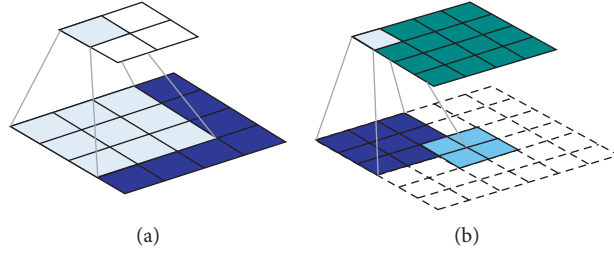


FIGURE 3: Schematic diagram of (a) convolution and (b) deconvolution in upsampling.

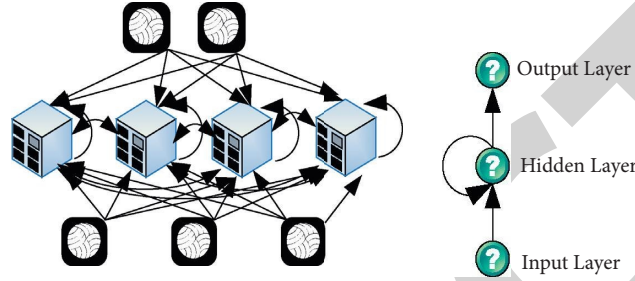


FIGURE 4: Schematic diagram of the middle-level structure of the RNN model.

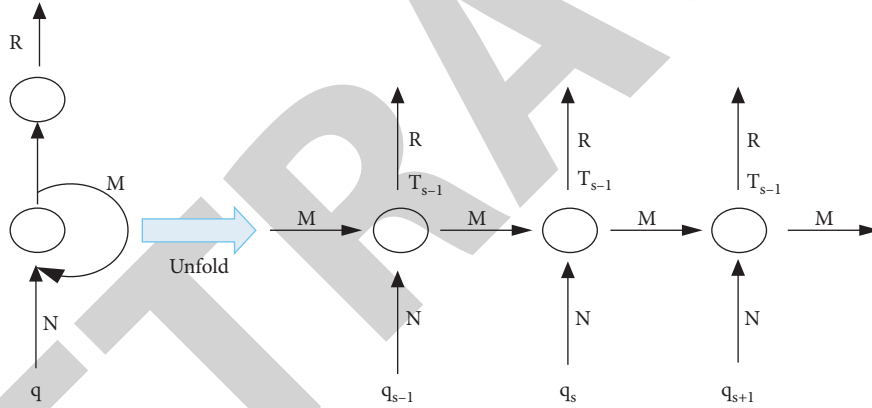


FIGURE 5: Schematic diagram of hidden layer expansion.

$$\frac{\alpha H_5}{\alpha M} = \frac{\alpha H_5}{\alpha c_5} \frac{\alpha c_5}{\alpha t_5} \frac{\alpha t_5}{\alpha M} \quad (5)$$

At this time, it can be found that, in addition to  $M$ ,  $t_5$  and  $t_4$  at the previous moment are also related. According to the equation  $T_s = f(M \cdot T_{s-1} + N \cdot q_s)$ ,  $t_5$  can be extended; namely,

$$\frac{\alpha H_5}{\alpha R} = \frac{\alpha H_5}{\alpha c_5} \frac{\alpha c_5}{\alpha R} \quad (6)$$

The expansion of  $t_4$  can be expressed as

$$\frac{\alpha t_4}{\alpha M} = \frac{\alpha t_4}{\alpha t_4} \cdot \frac{\alpha t_4^+}{\alpha M} + \frac{\alpha t_4}{\alpha t_3} \cdot \frac{\alpha t_3}{\alpha M} \quad (7)$$

At this time,  $t_1$  can be extended; namely,

$$\frac{\alpha t_1}{\alpha M} = \frac{\alpha t_1}{\alpha t_1} \cdot \frac{\alpha t_1^+}{\alpha M} + \frac{\alpha t_1}{\alpha t_0} \cdot \frac{\alpha t_0}{\alpha M} \quad (8)$$

Integrate the three equations:

$$\frac{\alpha t_5}{\alpha M} = \sum_{r=1}^5 \frac{\alpha t_5}{\alpha t_r} \cdot \frac{\alpha t_r^+}{\alpha M} \quad (9)$$

We can get

$$\frac{\alpha h_5}{\alpha M} = \sum_{r=0}^5 \frac{\alpha h_5}{\alpha c_5} \frac{\alpha c_5}{\alpha t_5} \frac{\alpha t_5}{\alpha t_r} \frac{\alpha^+ t_r}{\alpha M} \quad (10)$$

Equation (9) can show that  $t_5$ 's derivative  $M$  is not affected by  $t_4$  and the update of  $N$  is similar to  $M$ . The expression equation is

$$\frac{\alpha H_5}{\alpha M} = \sum_{r=0}^5 \frac{\alpha H_5}{\alpha c_5} \frac{\alpha c_5}{\alpha t_5} \frac{\alpha (M^{5-r} a_r)}{\alpha N} \quad (11)$$

Finally, the update method of  $R$  is only related to the output 0, and the update equation expression of  $R$  is



$$\frac{\alpha H_5}{\alpha R} = \frac{\alpha H_5}{\alpha c_5} \cdot \frac{\alpha c_5}{\alpha R} \quad (12)$$

**2.3. Pooling Method of Convolutional Neural Network.** In convolutional neural networks, pooling operations are usually used after convolution [17]. Through pooling, the feature vector output by the convolutional layer can be reduced, making it less prone to overfitting. As we all know, “static” is the biggest attribute of an image. In an image, the discriminative features of one area point are very likely to be applicable to other areas [18, 19]. Therefore, it appears to calculate the mean or maximum value of the features in a certain area of the image and use it to represent the features of the area. The following will introduce 4 common pooling methods.

- (1) General pooling: it is mostly used where there is no overlap in a certain image, which is also different from the convolutional layer. In general, pooling each window is unique, and it can also be understood that the window size is the same as the step size [20].
- (2) Average pooling: on the basis of general pooling, the average value of the area corresponding to the window needs to be calculated as the pooled value of the area [21].
- (3) Max pooling: on the basis of general pooling, it is necessary to calculate the maximum value of the area corresponding to the window and use it to represent the pooling value of this area [22].
- (4) Stochastic pooling: it is a simple and effective way to standardize CNN. It can reduce the overfitting of max pooling and improve the generalization ability. For the input of the pooling layer, based on the polynomial distribution of the input, a value is randomly selected as the output [23].

### 3. Volleyball Serve Experiment Based on Multilayer Features of Neural Network

Based on the improved human pose estimation technology, this chapter constructs a pose-based action evaluation index. And, based on this, a comparative analysis of volleyball serve moves, forming an automated method to compare and assess the quality of volleyball serve. It can provide valuable information for volleyball training [24]. This article selects 6 volleyball players as sample data. Under the mechanism of attention, attention in computer vision is to make the system learn to focus on the area of interest. On the one hand, neural networks with attention mechanisms can learn attention autonomously. On the other hand, the attention mechanism can help us understand the world that the neural network sees.

During data collection, the hardware part and the software part are required to cooperate to complete. The design of the hardware part is mainly the placement angle of the camera and the parameters of the camera body, and the software part defines the data collection interface. The base class camera of the data acquisition software interface

provides five functions, which are used to detect the camera, set the camera ID, parameter setting, and display, and obtain continuous image output through the function outputting. The standard volleyball court is rectangular, with a length of 18 meters, a width of 9 meters, and a barrier-free area of at least 3 meters. The center line divides the field into two areas, each with an offensive line 3 meters from the center line. Suppose here that the volleyball player is doing serve training at the bottom line of the left area in the figure.

On the other hand, the attention mechanism can help us understand the world that the neural network sees [25, 26]. The design of the hardware part is mainly the placement angle of the camera and the parameters of the camera body, and the software part defines the data collection interface [27]. The base class camera of the data acquisition software interface provides five functions, which are used to detect the camera, set the camera ID, parameter setting, and display, and obtain continuous image output through the function outputting [28, 29]. In the process of video-based action alignment, it is not accurate to directly calculate the Euclidean distance between the joint points of the two poses. Here, we will extract the key features for the alignment of the pose sequence and then normalize the pose features [30].

#### 3.1. Attitude Preprocessing

**3.1.1. Joint Coordinate Processing.** As shown in Figure 6, the joint points of the human skeleton posture, each node has its coordinates, temporarily represented by  $(A, B)$ . Considering the characteristics of the body, the neck is the most stable part. We use the neck as the origin to recalculate the joint coordinates to solve the problem of inconsistent coordinates. The translation equation of the coordinate system is

$$\begin{aligned} A' &= A - bA, bA = A_0, \\ B' &= B - bB, bB = B_0. \end{aligned} \quad (13)$$

In the equation,  $bA, bB$  represents the position offset of the origin of the coordinates in the directions of the  $A$ -axis and the  $B$ -axis. The offsets are equal to the  $A$  and  $B$  coordinates of the neck on  $A_0, B_0$ , respectively.

Depending on the resolution of the image, the length and body shape of each person's limbs will be different, and the style will be scaled in equal proportions, as shown in Figure 7.

**3.2. Attitude Distance Calculation.** In the process of video-based action alignment, it is not accurate to directly calculate the Euclidean distance between the joint points of the two poses. Here, we will extract the key features for the alignment of the pose sequence and then normalize the pose features. The smaller the characteristic distance between the two postures, the more similar the postures. Conversely, the larger the characteristic distance between the postures, the greater the posture difference. First, we convert each group of 17 key points into vectors and draw them all in a high-dimensional space:

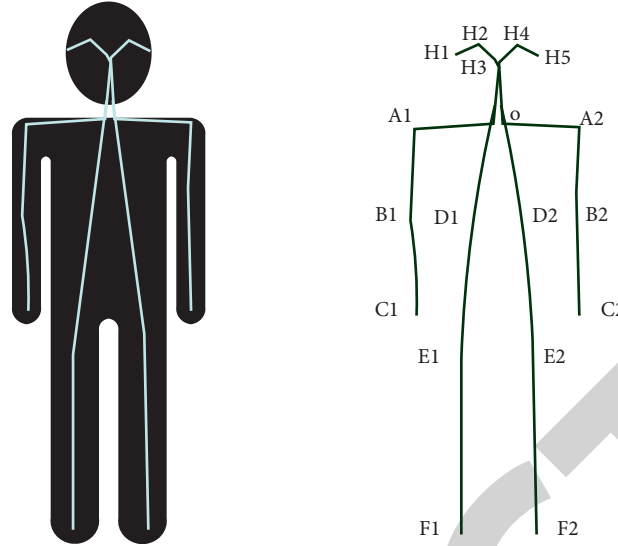


FIGURE 6: Schematic diagram of human posture skeleton.

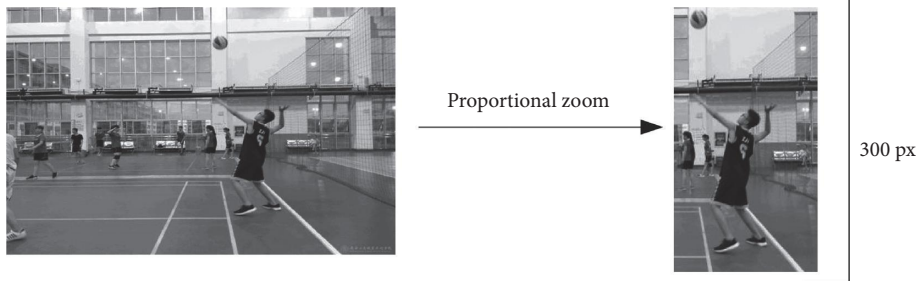


FIGURE 7: Pose proportional zoom.

$$Q = (A_1, A_2, \dots, A_{17}, B_1, B_2, \dots, B_{17})M = (m_1, m_2, \dots, m_{34}), \quad (14)$$

Then, the similar measurement task of the two poses will be transformed into calculating the angle between the two vectors, and we use the cosine similarity to calculate the angle. However, based on the coordinate system centered on the neck, the direct cosine similarity calculation will encounter some problems. The main action is that when the athlete jumps to serve, there will be two steps before the jump, so the distance between the feet will be a good description of the athlete's moment. After the athlete jumps off the ground, the right arm will rotate vigorously before hitting the ball. The angle of the right arm is also an ideal feature.

Normalize the posture information:

$$\begin{aligned} \text{norm}(q)' &= \sqrt{A_1^2 + A_2^2 + \dots + A_{17}^2 + B_1^2 + B_2^2 + \dots + B_{17}^2}, \\ A'' &= \frac{A'}{\text{norm}(q)'}, \\ B'' &= \frac{B'}{\text{norm}(q)'}. \end{aligned} \quad (15)$$

After recalculating the coordinates and normalizing the two skeleton vectors  $q_1$  and  $q_2$ , using cosine to express the distance between the twois

$$Di(q1'', q2'') = \sqrt{2 \cdot (1 - \text{conSim}(q1'', q2''))}, \quad (16)$$

Based on the problem of different confidence levels, the skeleton distance equation can be expressed as

$$Di(q1'', q2'') = \frac{1}{\sum_{r=1}^{34} Tr} \times \sum_{r=1}^{34} (q1_r'' - q2_r''), \quad (17)$$

### 3.3. The Trajectory and Function of the Throwing Arm. (1)

Tossing time: the time it takes for the throwing arm to throw the ball up is the time to throw the ball. The longer the tossing time is, the longer the athlete can hit the ball, and it can give enough time for the body to push upwards.

(2) The height of the throwing arm from the ground: whether the throwing height is reasonable is a key link in the throwing technique. The height of the tossing arm plays a decisive role in the height of the tossing. Whether the height of the tossing is appropriate is the most important factor in whether the

TABLE 1: The height of the throwing arm from the ground and the height of the throwing ball after the ball leaves the hand.

Serial number	Height	Throwing arm high above the ground	Account for height (%)	Toss height
A	1.85	1.8	97.3	3.3
B	1.82	1.8	99.5	3.27
C	1.8	1.8	99.4	3.3
D	1.8	1.78	98.4	3.28
E	1.85	1.8	95.3	3.27
F	1.84	1.83	99.5	3.5
Average value	1.83	1.8	98.2	3.3

whole serving rhythm is reasonable. Therefore, it is also one of the key factors affecting the quality of serving.

For the convenience of registration, the professional athletes who collected the samples were drawn and sorted by letters from A to F, and then the height, throwing height, and arm height of the six athletes were detected, and the height and throwing height were calculated. The basic information of the detection is as follows:

The height of the throwing arm from the ground corresponds to the height of the throwing ball and the time of throwing the ball. The moment the ball is thrown away from the hand and the arm of the throwing ball is higher than the ground, the height of the throwing ball will be higher, and the throwing time will be longer. Since the height of the toss reflects the strength of the lower limbs and the rebound amplitude of the trunk back, it is a condition for striving for the height of the hitting point. Therefore, ensuring the height of the throwing arm from the ground is the basis for ensuring the throwing height and success rate, to ensure the space and time of the athlete's lower limbs. It can be seen from Table 1 that the height of the throwing arm from the ground accounts for 98% of the height on average. From an individual point of view, F athlete's throwing arm is the highest from the ground, accounting for 99.52% of the height, and the throwing height is also the highest. Although the height of E athlete's throwing arm from the ground is not the lowest, it accounts for the lowest percentage of height, accounting for 95.26% of the height. In Table 1, the throwing time used by E is the shortest.

- (3) Analysis of the vertical movement trajectory of the throwing arm:

Figure 8 uses the vertical line as the standard to see if the athlete's throw is close to vertical. The vertical angles of A, B, and C of the experimental objects are small, less than  $9^\circ$  close to the vertical line, the thrown ball is vertical, and the throwing ball has high stability. The ball is close to vertical, which is helpful for the athlete to better judge the position of the ball and can ensure the stability of the athlete's next swing.

- (4) The angles of the shoulder, elbow, and wrist joints of the throwing arm from the moment the ball leaves the hand to the highest point of the throwing ball are as follows.

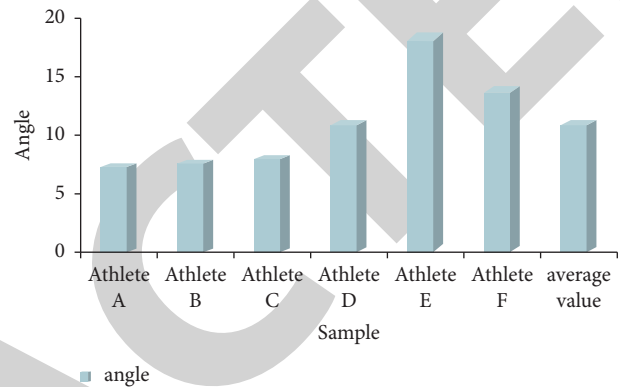


FIGURE 8: The angle of the perpendicular to the highest point of the toss.

TABLE 2: Changes in the angles of the shoulder, elbow, and wrist joints of the throwing arm from the ball to the highest point.

Serial number	Throw the ball away			Toss the ball to the highest point		
	Shoulder	Elbow	Wrist	Shoulder	Elbow	Wrist
A	108.9	163.4	171.1	156.5	169.5	212.7
B	113	162.1	171.4	158.6	170.7	219.1
C	110.9	159.4	171	151.7	167.6	214.7
D	96.7	158.1	169.3	149.1	169.3	189.5
E	96.7	154.1	167.3	141.3	158.7	187.3
F	100.3	153.6	170.3	150.2	155.4	188.6
Average value	104.4	158.4	170.1	151.2	165.2	202

For the athletes from A to F, the angles of the shoulder joint, elbow joint, and wrist joint are detected at the moment of throwing the ball and when the ball reaches the highest point. The results are as follows:

The throwing arm should be fully extended during the upward throwing process, and there should be no elbow flexion, throwing, or forceful throwing action with the fingers backwards. Toss the ball according to the reasonable trajectory of the throwing arm and the correct angles of the shoulder, elbow, and wrist joints to ensure that the trajectory of the throwing ball is relatively stable. Keeping the throwing arm extending upward and forward is helpful to judge the position of the hitting point, and it is easy to achieve the purpose of precise control of the throwing ball. Table 2 and Figure 8 show that the elbow joints of the



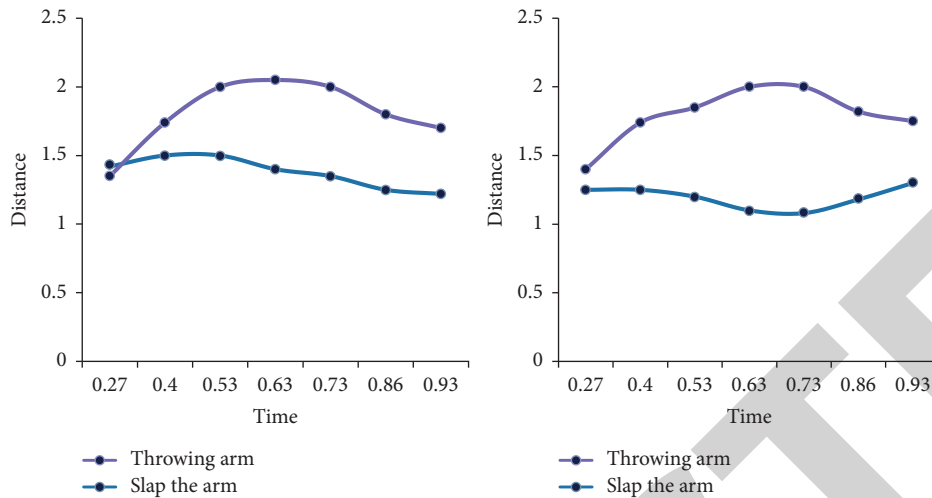


FIGURE 9: The trajectory of the two arms in the process of throwing the ball.

experimental subjects' shoulder joints, elbow joints, and wrist joints are relatively stable during the ball throwing process. The angle of the wrist joint increased from close to 180 degrees to more than 180 degrees, and the shoulder joint increased from 100.3 to 150.2 degrees at the moment of leaving the hand. In the process of throwing the ball, the main movement of the throwing arm is an upward movement driven by the shoulder joint. From the analytical data, it can be seen that the shoulder and elbow joints of the throwing arm of the athlete are not straight when throwing the ball away from the hand and the average is about 150.2° and 155.4°. The closer the shoulder and elbow joints are to 180°, the more stable the ball will be. Failure to meet the standard will result in low ball stability. The elbow joint of the experimental subject has a small change of 6.8°, and the wrist joint has a larger change, with a change of 32°. This shows that the subject's elbow joint is relatively stable and the wrist joint movement is large, which will affect the stability of the throwing ball.

- (5) Tossing rhythm during the tossing stage: because the individual differences of athletes, the height, height of the tossing, and personal habits are not used, there is a slight difference in the rhythm of the tossing of the athletes. However, generally speaking, the tossing rhythm in the serve action is composed of slow to fast and balanced force.

It can be seen from Figure 9 that the data of both arms have a downward trend. As the tossing arm lifts the ball, the batting arm directly charges backwards to do elbow bend and shoulder-sinking movements, and the body's center of gravity also shifts forward and downwards as the tossing arm lifts. Therefore, the height of the arms has also decreased. The throwing arm first starts to throw the ball upwards and then holds the racket arm directly back to accumulate energy, forming a posture of accumulating energy. The throwing arm increased from 1.4 meters to 1.75 meters, showing a downward trend from 0.73 to 0.93

seconds, while the batting arm did not change significantly. It grew from 1.25 meters to 1.3 meters and began to show a downward trend at 0.64 seconds. 0.53 seconds is the moment the ball leaves the hand. At this stage, the racket arm starts to draw the racket, and the data shows a downward trend.

#### 4. Volleyball Arm Trajectory Based on Neural Network

4.1. *The Arm Trajectory during the Hitting Stage.* The swinging and hitting stage is the main stage of force in the serve. All techniques in the throwing stage are to be able to hit the ball better during the swinging and hitting stage and deliver a high-quality ball.

The functions of the nonhitting arm are as follows: to ensure the stability of the toss during the serve, to assist the force when jumping the serve and spiking; to increase the means of attack, to maintain the balance and support of the body, and so on. Through the comparison of the pictures, it can be seen that the input action is consistent with the body curve baseline of the standard action, but the waist and legs do not exert backward force, and the waist strength is insufficient, which affects the hitting force.

As shown in Figures 10 and 11, when the ball rises to the highest point, the angle of the arm and shoulder joint of the throwing ball is about 148 degrees, and the body presents the state of top hip. The joint angle of the throwing arm is 148, and the joint angle of the slap arm is 79. The transition from the action to the next action is that the articulation of the throwing arm shows a downward trend, while the batting arm shows an upward trend, forming a kind of angular balance between the two arms. On the whole, the balance formed by the two can keep the volleyball player's body in balance. The throwing arm assists the batting arm in the process of hitting the ball upwards.

Combining Table 3 and Figure 12, when the ball is removed from the hand, the shoulder joint of the throwing arm is higher than the shoulder joint of the slap arm, the shoulder joint of the throwing arm is 0.34

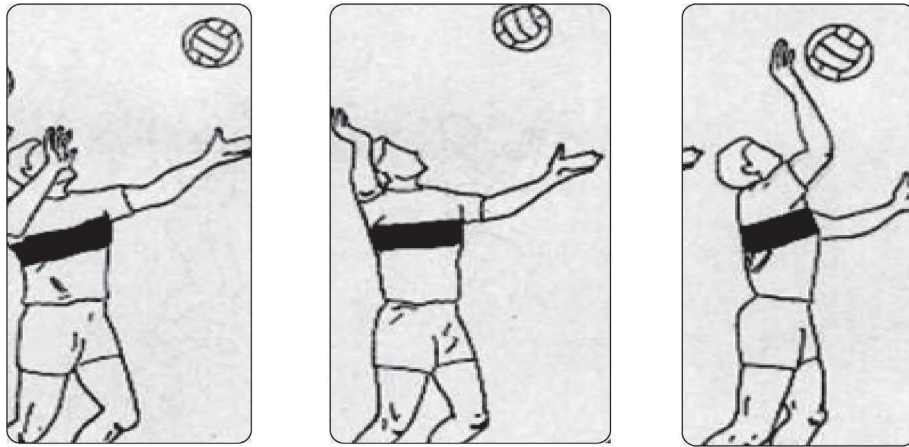


FIGURE 10: Schematic diagram of serving action.

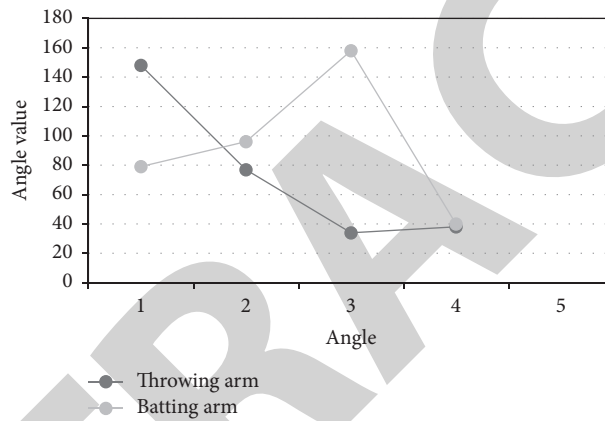


FIGURE 11: The relationship between the angle changes of the shoulders.

TABLE 3: The distance between the shoulder joint of the slap arm and the horizontal line.

Serial number	Ball off hand	The highest point of the toss	Back scratching	Hitting moment	End of action
A	0.42	0.69	0.35	0.19	0.5
B	0.4	0.75	0.25	0.1	0.57
C	0.44	0.8	0.29	0.21	0.46
D	0.46	0.85	0.26	0.23	0.46
E	0.36	0.66	0.26	0.1	0.38
F	0.34	0.91	0.27	0.1	0.48
Average value	0.4	0.77	0.28	0.14	0.48

meters, and the shoulder joint of the slap arm is 0.40 meters; the difference is not big. On the same level, the shoulder joint of the throwing arm is closer to the horizontal line. At this time, the function of the throwing arm is mainly to throw the ball upwards. When the ball is tossed to the highest point, the shoulder joint of the throwing arm is still higher than the shoulder joint of the slap arm, the shoulder joint of the throwing arm is 0.5 meters, and the shoulder joint of the batting arm is 0.8 meters; the difference is large. It forms a posture where the tossing arm shoulder joint is holding the racket arm shoulder joint, the tossing arm shoulder joint is closer to the horizontal line, and the slap arm shoulder joint is minimized. At this time, the function of the throwing

arm is to fully extend backwards, creating conditions for the top hip movement, and to make the slap arm the lowest point of the power reserve before hitting the ball. At the end of the final action, the shoulder joint of the throwing arm and the shoulder joint of the slap arm are almost back to the same level. The shoulder joint of the throwing arm is 0.4 meters, and the shoulder joint of the hitting arm is 0.5 meters. In the whole serving action, the tossing arm shoulder joint and the slap arm shoulder joints complete each stage of the action in this one-up and one-down sequence. The shoulder joints of both arms are balanced and hard, and the throwing arm plays a role in balancing the body, driving the rhythm, and assisting the force at all stages.

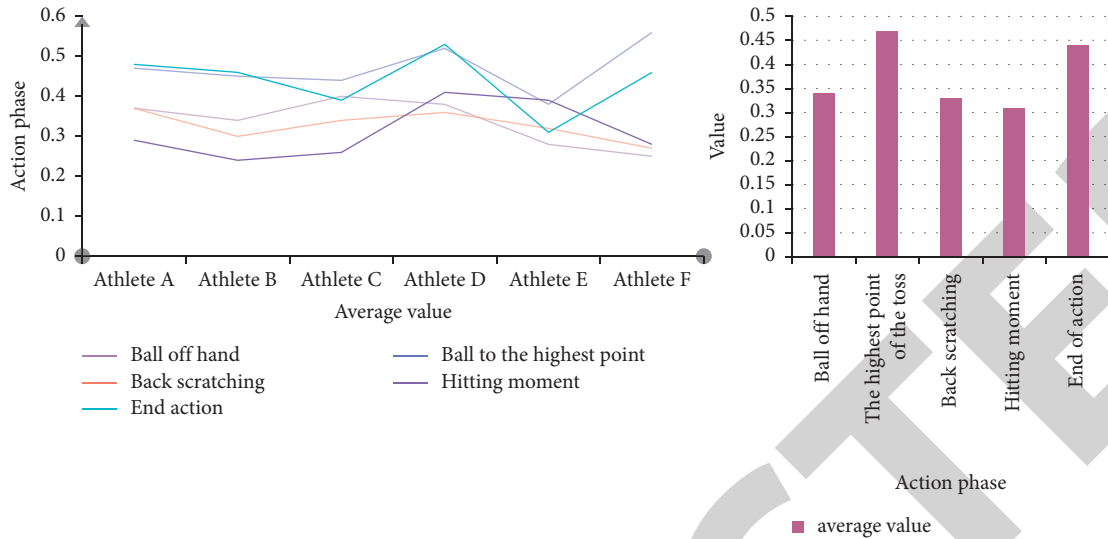


FIGURE 12: The distance between the shoulder joint of the throwing arm and the horizontal line.

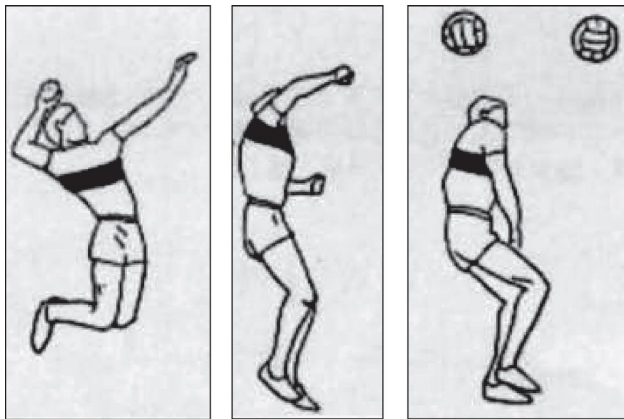


FIGURE 13: The trajectory diagram of the arm of the crank arm type ending action.

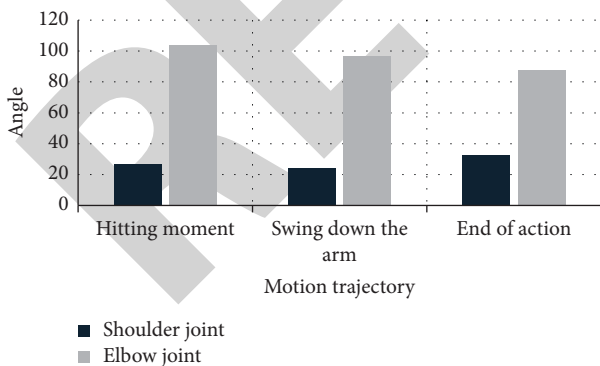


FIGURE 14: The angle of the lower shoulder and elbow changes at the end of the crank arm.

#### 4.2. The Arm Trajectory of the Crank Arm End Action

4.2.1. *Trajectory of the Throwing Arm at the End of the Crank Arm.* For example, Figure 13 is a diagram of the arm's trajectory and action at the end of the crank arm, and

Figure 14 is a diagram of the angle changes of the shoulder and elbow joints of the throwing arm. It can be seen from Figure 14 that, at the end of the action, the two trajectory lines overlap at the end of the trajectory. Because it is a curved arm ending action, the throwing arm remains at the abdomen position after the hit. From the action diagram in Figure 13, the tossing arm of the curved arm ending action is retracted to the abdomen position after the ball is hit, mainly to assist the torso in the abdomen movement. From Figure 14, there is a slight downward trend in the elbow joint, from 104 at the moment of hitting to 97° at the end of the action, and the change is not obvious. There is no obvious change in the shoulder joint from the moment of hitting the ball to the lowering of the ball. There is a slight upward trend in the process from the hand down to the end of the action, from the downward swing of 24° to 33° at the end of the action. The data shows that, from the time the ball is shot to the end of the action, there is no obvious change in the shoulder and elbow joints, the angle remains stable, and the trajectory of the movement is also stable. It is good for keeping the balance of the body after the abdomen is closed and the action is over.

#### 4.2.2. The Function of the Throwing Arm of the Crank Arm Type Ending Action

(1) *Auxiliary Force.* As shown in Figure 15, from the angle changes of the shoulder and elbow joints of the throwing arm, after the moment of hitting the ball, it is the process of the ball flying forward and the shooting arm moving forward and downward. At this time, the torso is continuing to rotate and move the upper body forward and downward, and the angular velocity of the shoulder and elbow joints has increased significantly. It shows that the shoulder and elbow joints of the tossing arm can play the role of assisting force in the process of pressing the arm downwards after hitting the ball, mainly assisting the forward and downward force of the slap arm.

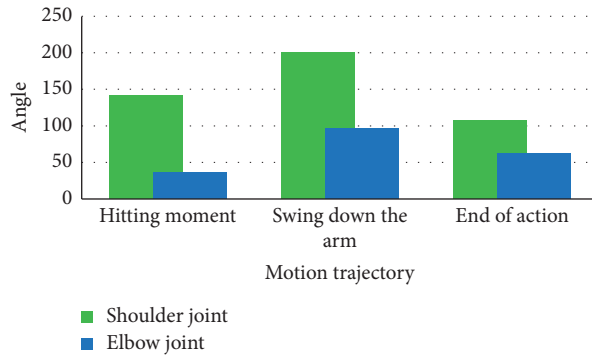
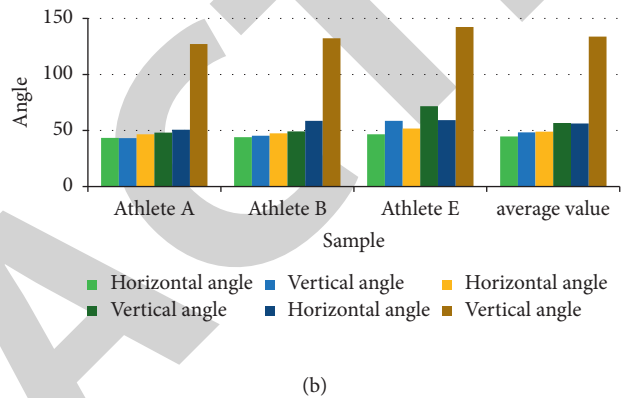
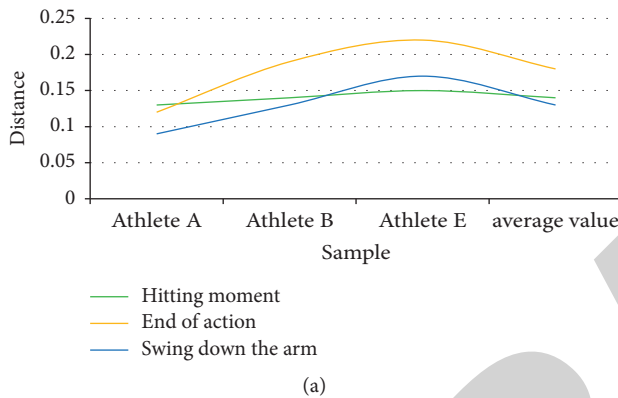


FIGURE 15: Angle changes of the shoulder and elbow joints at the end of the crank arm.



(a)

(b)

FIGURE 16: The distance between the forearm and the body and the angle of the horizontal vertical line at the end of the bent arm.

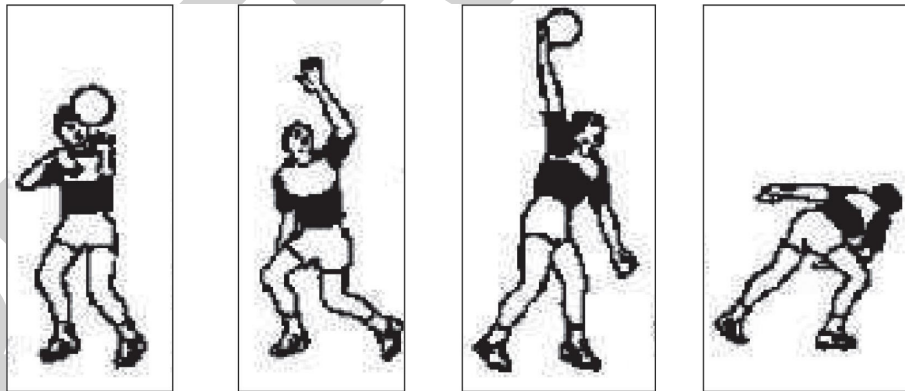


FIGURE 17: The arm movement trajectory of the back swing and action hitting the ball.

(2) *Auxiliary Torso Rotation and Abdomen Function.* Figure 16(a) shows the schematic diagram of the distance from the forearm to the body. From the perspective of the overall direction, the forearm is closer to the body at the end of the curved arm action, and the distance between the forearm and the body at the moment of hitting and the end of the action is 0.14 m and 0.18 m. It shows that, from the moment of hitting the ball to the end of the action, the distance from the forearm to the body does not change much and it is closer to the body. As shown in Figure 16(b), the horizontal angle of the forearm does not change much at the end of the crank arm, but the vertical angle is gradually increasing. Combining with the trajectory of the

arm when throwing the ball, the angle of the forearm close to the abdomen, shoulder, and elbow joints and the increase in speed in the curved arm ending action are all conducive to the downward pressure of the trunk and the racket arm after the ball is hit. The closer the forearm is to the body, the more it can bend the arm, speeding up the torso and reducing the abdomen. Generally speaking, when the arm of the throwing ball is closer to the abdomen, the horizontal angle is stable, and the vertical angle increases. The increase in angular velocity is conducive to the abdomen movement of the trunk and assists the turning and pressing of the body's center of gravity to complete the final ending movement.

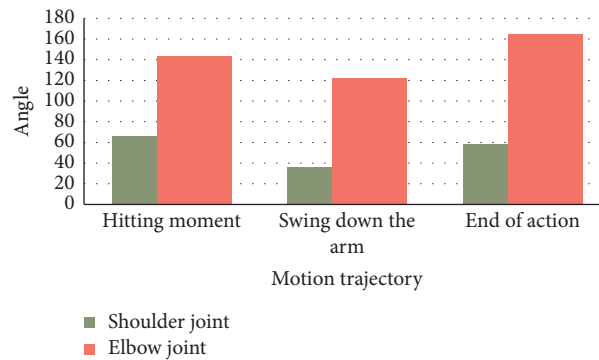


FIGURE 18: The angle changes of the shoulder and elbow joints at the end of the back swing.

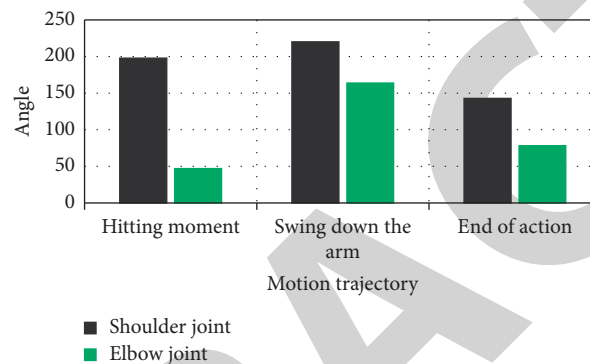


FIGURE 19: Angle changes of the shoulder and elbow joints of the throwing arm.

#### 4.3. The Running Trajectory of the End Action Arm

4.3.1. *Trajectory of the Throwing Arm at the End of the Backward Swing.* Figure 17 shows the trajectory of the arm movement at the end of the back swing, from the moment of hitting the ball to the end of the movement, and the gap between the two increases in segments. The data shows that when the arm is pressed down after the ball is hit, the shoulder and elbow joints of the throwing arm that end the swing in the back swing can also play an auxiliary force role. It can be seen from Figure 18 that the angles of the shoulder and elbow joints of the back swing type are greater than the angles of the shoulder and elbow joints at the end of the curved arm type. The data shows that the angle of the elbow joint has a downward trend from the moment of hitting the ball to the downward swing, from  $144^\circ$  to  $122^\circ$ . And when the batting arm swings forward and down at the end of the action, there is a significant upward trend, from the  $122^\circ$  downward rise of the batting arm to  $165^\circ$  at the end of the action; the change is more obvious.

#### 4.3.2. The Function of the Throwing Arm of the Back Swing End Action

(1) *The Role of Auxiliary Forces.* Figure 19 shows the angle change diagram of the shoulder joint and elbow joint of the throwing arm. The change values of the shoulder and elbow joints of the back swing type ending movement are greater

than the change values of the crank arm type ending movement. The data shows that when the arm is pressed down after the shot, the shoulder and elbow joints of the throwing arm that end the swing back swing can also play an auxiliary force.

(2) *The Role of Auxiliary Rotation.* As shown in Figure 20(a), as a whole, the forearm is far away from the body, and the distance at the moment of hitting the ball and the distance at the end of the action are 0.34 m and 0.45 m, respectively. As shown in Figure 20(b), in the finishing action of the back swing, the forearm of the throwing arm has a relatively high degree of change in the horizontal and vertical angles, showing a more obvious undulating state. During the time the ball is flying away from the hand, the arm gradually moves backward, and the vertical angle between the forearm and the body is close to 180 degrees.

Through the data statistics of the appeal, the two ending actions are compared. Comparing these two ending actions, the throwing arm in the first type of curved arm ending action can play a more important role in assisting the force. The main reason is that the throwing arm of the curved arm ending action is closer to the abdomen of the body, the angle of the shoulder and elbow joints of the throwing arm is smaller, and the angle change with the horizontal and vertical lines is small. These are conducive to the depression of the torso and can assist the force and complete the serve action. Although the ending action of the second back swing has the effect of assisting the body to press down, because the throwing arm is far from the body, the angle of the shoulder



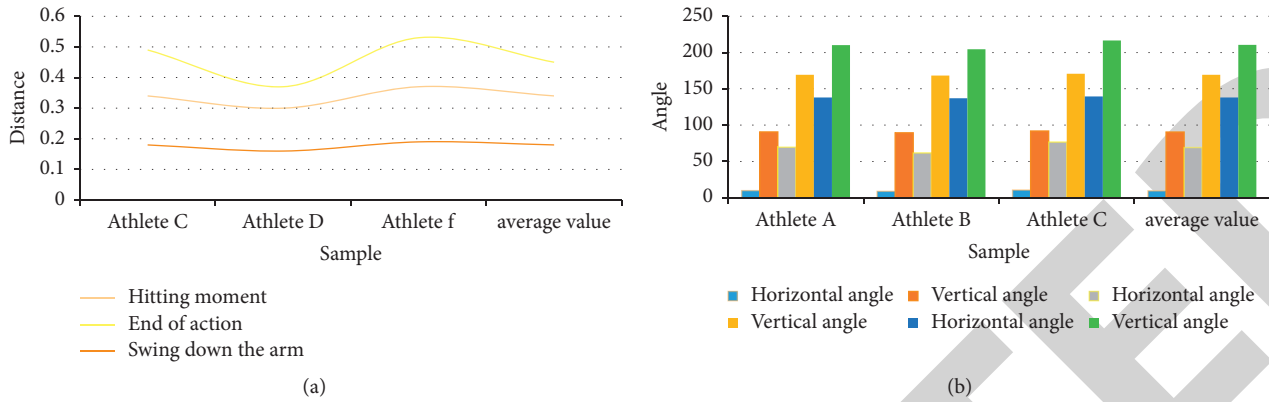


FIGURE 20: The distance between the forearm and the body and the angle of the horizontal and vertical lines at the end of the back swing.

TABLE 4: Comparison of recognition degrees of different algorithms.

Method	Single person behavior recognition (%)	Group behavior recognition (%)
Algorithm	85.8	83.8
Two-stage Hierarchical Model	81.9	—
CERN	83.3	69
Social Scene	83.8	81
Hierarchical LSTM	70.3	—

joint and the elbow joint of the throwing arm is larger. The angle changes of the horizontal and vertical lines are also large, and the effect is not as good as the crank arm type. In addition, the trajectory of the throwing arm of the swing back ending action tends to swing backwards by a large margin when the action is about to end. Although it is conducive to body rotation, it is not conducive to maintaining balance and will cause excessive rotation. The trajectory of the throwing arm of the crank arm ending action swings back slightly. That is to say, it can assist in turning and pressing down, and it can also maintain the balance of the body in the process of turning and prevent excessive turning.

As shown in Table 4, under the condition of the same dataset and two tasks being evaluated at the same time, the accuracy rate of the algorithm in this paper reaches 85.8% in group recognition and 83.8% in single person recognition. All are significantly higher than Two-stage Hierarchical Model, CERN, Social Scene, Hierarchical LSTM, and other algorithms. The experimental results show that the use of attention mechanism helps to better enhance the feature representation and greatly improves the recognition accuracy and its effectiveness is verified.

## 5. Conclusion

The running trajectory of the throwing arm is divided into two different running trajectories: the crank arm type and the back swing type. Comparing the two running trajectories, the curved arm running trajectory has a small radian and is close to vertical, and the throwing of the ball is relatively stable, which is conducive to the movement of the trunk and abdomen. The back swing type has a large arc;

during the flight of the ball, the forearm of the throwing arm begins to swing to the left and rear of the body. The angle between the forearm and the vertical was almost  $180^\circ$ , and the angle between the forearm and the vertical line increased from  $90^\circ$  to more than  $180^\circ$ . At the end of the action, the throwing arm is straight behind the left side of the body and the throw is unstable, which will cause excessive rotation. The throwing arm is 98% of the height above the ground. The horizontal angle of the throwing arm at the moment the ball leaves the hand is positively correlated with the throwing time and height. The reasonable running trajectory has an impact on the stability of the throwing ball. The closer the trajectory of the tossing arm is to the vertical, the more stable the tossing is. Crank arm ending action has a more positive effect on serve than the back swing ending action. The distance between the forearm and the body at the end of the movement is 0.18 meters, with a minimum of 0.12 meters and a maximum of 0.22 meters. The overall look is very close to the body, close to the abdomen. The bent arm style is closer to the abdomen, which is good for the torso to press down and play a role in assisting the force. The back swing is far from the abdomen, which is conducive to torso rotation, but too much swing back will cause excessive rotation. It is necessary to pay attention to the importance of the throwing arm trajectory, and practice according to the reasonable trajectory of the throwing arm. In this way, the stability of the throwing ball is strengthened, the drop of the throwing ball is reduced, and the time of scratching the ball is shortened. By strengthening the stability of the upward throwing trajectory of the throwing arm, the arc is reduced, the ball is closer to the vertical, and the stability of the throwing ball is increased. When throwing the ball, pay

attention to the angle of the throwing arm to be close to 45 degrees. Increasing the angle of the joints of the throwing arm when throwing the ball upwards, the angle between the high point and the vertical line of the ball is close to perpendicular. In the future, tossing the ball, the elbow joints, wrist joints of the tossing arm, and the movement trajectory of the tossing arm should be kept fixed. And it ensures that the height of the arm of the throwing ball is the same as the height at the moment the ball is thrown away from the hand, which increases the control distance of the ball [25–30].

## Data Availability

All the data used are included within the article.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

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