BIOMECHANICAL ANALYSIS OF ACTIONS OF INSTEP CATCHING AND SHOOTING OF FOOTBALL PLAYERS

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Catching and shooting are key techniques in football. From the perspective of biomechanics, this study analyzed actions of instep catching and shooting of football players. Eight special football players from China Jiliang University were selected as research subjects. Pictures of the players were taken through the Vicon three-dimensional infrared high-speed camera, and the relevant data were processed using the supporting software. The results showed that the displacement and angle of different joints were different in the process of catching the ball, in which the displacement and angle of the knee joint were obvious and the changes of the hip and ankle joints were small; in the process of shooting, the thigh and shin swang backwards firstly and then forward, and the backward swing provide large power for the forward swing of the shin; in addition, the muscle moment of the hip joint was larger than that of the knee joint. The experimental results reveal some biomechanical characteristics of athletes in the process of catching and shooting and provide some theoretical bases for athletes to improve their technical level.

Keywords: football players; instep catching; instep shooting; biomechanics; Vicon system

1. Introduction

Football is a widely loved sport, known as "the first sport in the world". It is a multi-dimensional sport [1], including technical actions such as juggling, passing, catching and shooting. In the long development process, football technology and rules are improved step by step. With the enhancement of antagonism and competition in modern football games, the complexity and difficulty of various technologies have been further improved. Biomechanical analysis can help athletes understand the technical characteristics, grasp the skills as soon as possible, improve the technical level, and reduce the sports injury [2]. It has a very wide application in the study of sports such as basketball [3, 4], badminton [5, 6], swimming [7, 8], etc. and also has an application in the field of football [9]. Torreblanca-Martinez et al. [10] studied the effect of muscle fatigue caused by countermovement jumps (CMJ) on the speed of instep kicking of athletes. Through the experiment on the force measuring platform, it was found

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that the jumping height of athletes changed significantly after fatigue caused by CMJ compared with that before fatigue, but there was no significant difference in the kicking speed. Through the biomechanical analysis of 10 professional football male players, Greg [11] found that the thigh rotated for a long time and the shin rotated for a short time in the process of kicking, the pelvis rotated about 15 ° when touching the ball, and the peak torque of the knee extensor remained unchanged. Pereira Santiago et al. [12] studied the relationship between nationality and kicking performance. They took seven Brazilian players and seven Japanese players as subjects and photographed the work of the athletes by digital camera. The results showed that the lower limb kinematics of the athletes from the two countries were similar in the stage of support and kicking. Harry et al. [13] took 25 first-class male football players as research subjects, divided them into four groups, goalkeeping (GK), defensive (DEF), midfield (MID) and attacking (ATT), and asked them to do the largest vertical jumping and landing. The results showed that the peak value and loading rate of vertical ground reactive force (vGRF) of defenders were large and the attenuation rate of vGRF was also large. In the current research on the biomechanical characteristics of football, there are fewer studies on the instep catching and shooting movements, and the biomechanical characteristics of these two movements are still unclear. Therefore, this study mainly analyzed the biomechanics of actions of instep football catching and shooting, in order to understand the characteristics and rules of the two actions and improve the skill of catching and shooting and the competitive level. This paper provides a basis for coaches to formulate relevant training programs, helps students understand the main points of these two movements more deeply, master the movements faster and improve the technical level, and also provides some references for a better understanding of the injury mechanism in football.

2. Analysis of actions of instep catching and shooting

Catching and shooting are two important techniques in football and also important scoring means. Stable catching and accurate shooting are of decisive significance to win or lose the game. Commonly used kicking actions include inside foot kicking [14], instep inner edge kicking, instep outer edge kicking, instep front kicking [15], etc. This study mainly analyzed the catching and shooting actions of instep front.

(1) Instep front catching (Fig. 1)

The player moves in time according to the landing point of ball and approaches the ball with the instep front. At the moment that the ball contacts with the foot, the catching foot and ball withdraws synchronously, and the toe slightly cocks to catch the ball to the place where it is needed. The whole action can be divided into four parts: ① position selection stage: judge the route and landing point of the ball to occupy a favorable catching position; ② support stage: stable and reasonable support foot is conducive to control the ball in the required position; ③ touch stage: try to use the front half of the instep to catch the ball, which can play a good buffer role for the falling ball; ④ follow-up stage: after catching the ball, the center of gravity of the body should move quickly with the ball.

In the process of the game, it is necessary to catch the ball steadily and quickly, so as to reduce mistakes, attack quickly and create scoring opportunities.

Fig. 1. Instep front catching

(2) Instep front shooting (Fig. 2)

The player runs up in a straight line and put the support foot at the place which is 10-12 c m away from the ball side, accelerate the forward swing of the kicking leg with the hip joint as the axis, straighten the instep at the moment of touching the ball, fasten the toes, and hit the ball with the front of the instep. The whole movement can be divided into five parts: ① run-up: the direction and distance between people and ball are adjusted, so that the supporting foot can be in the correct position when kicking; ② position of supporting foot: the position of supporting foot should make the kicking leg achieve the maximum swing amplitude and speed; ③ swinging of kicking leg: the kicking leg should swing forward with the hip joint as the axis, and the shin should fully swing with an accelerated speed to obtain large kicking power when the knee joint approaches the right above of the ball; ④ touching the ball: the instep front kicks the back of the ball, and the hitting force should be as large as possible; ⑤ forward following: after shooting, with the front swing of the leg and the forward pushing of hips, the center of gravity is moved forward, and the inertia is eased to maintain the balance of the body.

Fig. 2 Instep front shooting

3. Subject and method

3.1. Research subjects

Eight football players from China Jiliang University were selected as the research subjects. All the players had no history of lower limb injury within 6 months, and the dominant leg was the right leg. No intense exercise was carried out within 48 hours before the experiment, and they all volunteered to participate in the experiment and signed the informed consent. The general information of athletes is shown in Table 1.

Table 1

The basic information of research subjects

	Age/year	Height/m	Weight/kg	Training years/n
A	22	176.33	68.24	10
B	21	178.41	67.33	11
C	22	176.27	67.49	15
D	22	177.16	68.32	13
E	23	178.28	66.85	11
F	22	176.36	68.54	12
G	21	175.42	69.33	14
H	22	178.19	67.21	14

3.2. Experimental instruments

The Vicon optical motion capture system was used to capture the movements of instep front catching and shooting of the athletes. The Vicon system is a three-dimensional motion capture system consisting of Vicon cameras and other related equipment, which has a wide range of applications in the field of virtual reality, sports rehabilitation and other fields. The Vicon MX system and its standard accessories (Oxford Metrics Limited, UK) were used. The sampling rate was 500 Hz. The resolution was 2,352 × 1,728. The reflective marker ball with a diameter of 14 mm was used to mark the athlete. The paste position of the reflective marker balls is shown in Fig. 3.

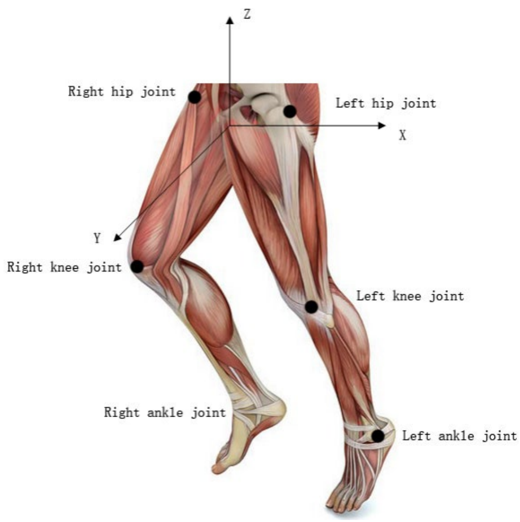

Fig. 3 The paste position of the markers

3.3. Experimental method

The experimental site was set up. The experimental instruments were calibrated. The research subjects dressed uniformly. Firstly, they warmed up for about 5 minutes on the treadmill and then did three to five times of adaptive exercise. The whole process of the instep front catching and shooting actions of the athletes was recorded by the Vicon system. The experimental personnel pasted the mark points on left and right hip joints, knee joints and ankle joints of the athletes, as shown in Fig. 3. When catching the ball, the ball feeder was about 10 m opposite to the catcher, and the ball speed was a little higher than the medium speed. When shooting, the goal was a circle with a diameter of 4 m and 15 m away from the player. The player ran up in 3-5 m and shot with the instep front in the largest power. Every player repeated each action three times, and the average value was taken.

3.4. Data analysis

The collected data were processed and analyzed using supporting software of Vicon and Excel. The research indicators were defined as follows.

(1) Hip joint angle: the angle between the line connecting the ipsilateral hip and knee joints and a vertical line (unit: °)

(2) Knee joint angle: the angle between the femur and the ipsilateral tibia (unit: °)

(3) Ankle joint angle: the angle between the tibia and the ipsilateral metatarsals (unit: °)

(4) Joint torque: it reflected the muscle control of the joints, which was obtained from inverse dynamics calculations, and it included the peak flexion and extension torques of the hip and knee joints in the sagittal plane, the peak abduction and adduction torques in the frontal plane, and the peak rotational inward and outward torques in the horizontal plane (unit: 100 Nm/kg).

4. Biomechanical results and analysis

4.1. Analysis of instep front catching

4.1.1 Changes of hip joint displacement

In the process of instep front catching, the displacement of the hip joint in different directions is shown in Table 2.

It was seen from Table 2 that the hip joint had a large displacement in three directions in the stage of position selection, i.e. - 567.52 ± 162.33 mm in the X direction, 933.25 ± 18.66 mm in the Y direction, and - 371.36 ± 37.25mm in the Z direction; in the support stage, the hip joint had a displacement of - 586.25 ±

163.33 mm in the X direction, 885.62 ± 45.67 mm in the Y direction, and - 70.68 ± 23.54 mm in the Z direction; in the touch stage, the displacement of the hip joint was - 567.23 ± 178.36 mm in the X direction, 1023.48 ± 38.64 mm in the Y direction and - 36.64 ± 17.68 mm in the Z direction; finally, in the follow-up stage, the displacement of the hip joint was - 596.25 ± 133.54 mm in the X direction, 931.66 ± 32.36mm in the Y direction and - 307.69 ± 32.86 mm in the Z direction. On the whole, the displacement of the hip joint did not change much in the process of catching the ball.

Table 2

Changes of hip joint displacement (unit: mm)

	X	Y	Z
Position selection	-567.52±162.33	933.25±18.66	-371.36±37.25
Support	-586.25±163.33	885.62±45.67	-70.68±23.54
Touch	-567.23±178.36	1023.48±38.64	-36.64±17.68
Follow-up	-596.25±133.54	931.66±32.36	-307.69±32.86

4.1.2 Changes of knee joint displacement

The changes of knee joint displacement in different directions are shown in Table 3.

Table 3

Changes of knee joint displacement (unit: mm)

	X	Y	Z
Position selection	-261.33±121.33	-502.33±137.64	428.11±35.62
Support	316.58±58.64	-483.12±139.54	998.64±136.54
Touch	378.62±67.34	-472.11±127.36	1067.86±46.59
Follow-up	-307.49±116.78	-481.22±165.49	436.85±24.32

It was seen from Table 3 that the displacement of the knee joint was - 261.33 ± 121.33 mm in the X direction, - 502.33 ± 137.64 mm in the Y direction, and 428.11 ± 35.62 mm in the Z direction in the stage of position selection; in the support stage, the displacement was 316.58 ± 58.64 mm in the X direction, - 483.12 ± 139.54 mm in the Y direction, and 998.64 ± 136.54 mm in the Z direction; in the touch stage, the displacement was 378.62 ± 67.34 mm in the X direction, -472.11 ± 127.36 mm in the Y direction, and 1067.86 ± 46.59 mm in the Z direction; in the follow-up stage, the displacement of the knee joint was - 307.49 ± 116.78 mm in the X direction, - 481.22 ± 165.49 mm in the Y direction, and 436.85 ± 24.32 mm in the Z direction. On the whole, the knee joint displacement had obvious changes in the process of catching.

4.1.3 Changes of ankle joint displacement

The changes of ankle joint displacement in different directions are shown in Table 4.

Table 4

Changes of ankle joint displacement (unit: mm)

	X	Y	Z
Position selection	-523.66±137.69	-548.33±101.36	155.66±29.48
Support	518.33±48.64	-548.96±106.35	691.37±51.26
Touch	488.96±51.68	-618.63±136.55	712.63±64.55
Follow-up	515.66±86.52	-578.64±95.81	73.66±17.24

It was seen from Table 4 that in the selection stage, the ankle joint displacement was - 523.66 ± 137.69 mm in the X direction, - 548.33 ± 101.36 mm in the Y direction, and 155.66 ± 29.48 mm in the Z direction; in the support stage, the ankle joint displacement was 518.33 ± 48.64 mm, - 548.96 ± 106.35 mm in the Y direction, and 691.37 ± 51.26 mm in the Z direction; in the contact stage, the ankle joint displacement in the X direction is 488.96 ± 51.68 mm; in the follow-up phase, the displacement was 515.66 ± 86.52 mm in the X direction, - 578.64 ± 95.81 mm in the Y direction, and 73.66 ± 17.24 mm in the Z direction. Similar to the hip joint, the displacement of the ankle joint changed little in the whole movement process.

4.1.4 Changes of joint angles

In the process of catching the ball, the angle changes of different joints are shown in Table 5.

Table 5

Angle changes of different joints (unit: °)

	Hip	Knee	Ankle
Position selection	93.33±2.33	121.33±9.78	112.33±4.86
Support	90.23±1.88	93.15±6.27	120.36±8.45
Touch	92.45±2.31	112.54±10.45	128.64±8.78
Follow-up	93.54±2.15	169.51±5.64	95.64±3.42

It was seen from Table 5 that the changes of hip, knee and ankle joint angles were 93.33 ± 2.33 °, 121.33 ± 9.78 ° and 112.33 ± 4.86 ° respectively; in the support stage, the angle changes of the three joints are 90.23 ± 1.88 °, 93.15 ± 6.27 ° and 120.36 ± 8.45 ° respectively; in the touch stage, the angles of the joints are 92.45 ± 2.31 °, 112.54 ± 10.45 ° and 128.64 ± 8.78 ° respectively; in the follow-up stage, the angle changes of the joints were 92.45 ± 2.31 °, 112.54 ± 10.45 ° and 128.64 ± 8.78 ° respectively; in the follow-up stage, the changes of angles were 93.54 ± 2.15 °, 169.51 ± 5.64 ° and 95.64 ± 3.42 ° respectively. On the whole, in the process of movement, the changes of hip and ankle joint angles were small, while the change of the knee joint angle was large, which showed that the contribution of the knee joint to the completion of movement was large.

4.2. Analysis of instep front shooting

4.2.1 Swing time of kicking leg

The swing time of the kicking leg of the player is shown in Fig. 4.

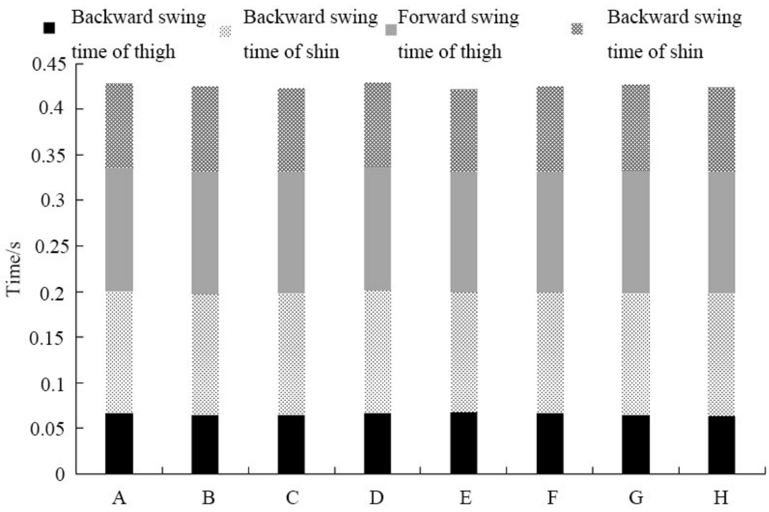

Fig. 4 The swing time of kicking leg

It was seen from Fig. 4 that the total swing time of different players and the swing time of different parts were similar in the swing process of the kicking leg, the backward swing time of thigh was short, the backward swing time of shin and the forward swing time of thigh were long, and the forward swing time of shin was also short. In the process of shooting, players could get fast forward swing after full backward swing and then obtain the full power to get a good shooting performance.

4.2.2 Hip joint muscle moment of kicking leg

The hip joint muscle moment of the kicking leg is shown in Table 6.

Table 6

Hip joint muscle moment of different athletes (unit: 100 Nm/kg)

	Peak bending moment	Peak extension moment	Peak abduction moment	Peak adduction moment
A	103.42	44.99	69.75	129.53
B	103.97	58.03	57.85	97.32
C	117.65	58.22	47.07	121.77

D	117.82	66.87	60.32	120.53
E	116.47	74.82	51.71	103.41
F	118.87	43.19	51.75	107.98
G	119.93	67.64	39.72	121.59
H	119.29	46.4	71.39	121.42

It was seen from Table 6 that the peak bending moment of the kicking leg was 103.42-119.93, the peak extension moment was 43.19-74.82, the peak abduction moment was 39.72-71.39, and the peak adduction moment was 97.32-129.53. The joint muscle moment can reflect the tension of the joint muscle group. After the kicking leg left the ground, there was a small extension moment which was smaller than the bending moment, which provided a small active backward swing for the thigh, and moreover, the bending moment prevented the forward swing of the thigh. In this process, there was also an adduction moment and an abduction moment which helped the kicking leg keep stable and improve the ability of orientation, so that the thigh could complete the action on the normal track.

4.2.3 Knee joint muscle moment of kicking leg

The knee joint muscle moment of the kicking leg is shown in Table 7.

Table 7

The knee joint muscle moment of different athletes (unit: 100 Nm/kg)

	Peak bending moment	Peak extension moment	Peak medial rotation moment	Peak lateral rotation moment
A	48.81	51.73	6.12	4.66
B	47.29	48.95	5.15	3.94
C	48.66	64.24	6.73	3.65
D	47.02	68.35	5.35	5.22
E	49.95	46.31	6.28	4.91
F	48.73	66.95	5.41	3.69
G	46.84	57.64	5.23	4.34
H	46.02	59.5	4.26	3.73

It was seen from Table 7 that the peak bending moment of the kicking leg was 46.02-49.95, the peak extension moment was 46.31-68.35, the peak medial rotation moment was 4.26-6.73, and the peak lateral rotation moment was 3.65-5.22. In the process of knee joint movement, there was also an extension moment to prevent the leg from swinging back in advance, so that the thigh could fully swing back, and then the bending moment provided the shin with a large backward swing speed, avoiding the excessive extension of the knee joint. However, compared with the hip joint, the knee joint muscle moment was smaller, indicating that the contribution of the knee joint was smaller in the shooting process.

5. Conclusion

In order to provide a professional guidance for the training of football players, this study analyzed the biomechanical characteristics of eight professional football players in the process of their instep front catching and shooting action. The results showed that:

(1) the displacement of hip, knee and ankle joints was different in the course of instep front catching, among which displacement changes of hip and ankle joints were small and displacement changes of the knee joint was large;

(2) in the process of instep front catching, the angle of the knee joint changed greatly, while angles of hip and ankle joints changed little;

(3) in the process of instep front shooting, the full backward swing of the thigh provided a large momentum for the forward swing of the shin, so as to obtain better shooting effect;

(4) in the process of instep shooting, the contribution of the knee joint was small from the perspective of the joint moment.

The research results of this study point out some biomechanical characteristics in the process of instep front catching and shooting and make some contributions to the arrangement of reasonable and scientific training plans, which is conducive to improving the technical level of athletes. In future research, this paper will further refine the feature analysis of the two movements by conducting a more in-depth study that considers the biomechanical characteristics of football players of different ages, genders, exercise levels, and fatigue levels as they perform the movements.

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