

Retraction

Retracted: The Biomechanical Analysis of Jumping Difficulty Movement in National Traditional Sports

Mobile Information Systems

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1].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.

In addition, our investigation has also shown that one or more of the following human-subject reporting requirements has not been met in this article: ethical approval by an Institutional Review Board (IRB) committee or equivalent, patient/participant consent to participate, and/or agreement to publish patient/participant details (where relevant).

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] L. Zhang and W. Yang, "The Biomechanical Analysis of Jumping Difficulty Movement in National Traditional Sports," *Mobile Information Systems*, vol. 2022, Article ID 7679116, 8 pages, 2022.

Research Article

The Biomechanical Analysis of Jumping Difficulty Movement in National Traditional Sports

Linbao Zhang ^{1,2} and Wei Yang ³

¹Physical Education College, Shangrao Normal University, Shangrao, Jiangxi 334001, China

²Cavite State University, Cavite 99900, Philippines

³Research Center Wujia School Suzhou University, Anhui, Suzhou 234000, China

Correspondence should be addressed to Wei Yang; 1700210465@stu.sqxy.edu.cn

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In order to explore the relevant factors and the completion of difficult movements, this paper is an important theoretical basis for improving and constructing the evaluation of athletes' movement quality. It presents a kinematic analysis of the difficult movements of competitive Tai Chi, taking the difficult movements of the swirl group of competitive aerobics as the research object. The data is collected by different methods. When completing difficult movements, due to different personal exercise habits, this paper takes the right leg as the swinging leg and the left leg as the take-off leg when completing the difficult movements. The test object in this paper adopts the traditional three-step up-step method. The starting time of the take-off stage is consistent with the illustration. By consulting experts for the stage division of the difficult movement, the two movement stages are equally divided into three stages according to the needs of the research: take-off, soaring, and landing. The results show that, from the moment the left foot hits the ground to the moment of maximum cushioning, the angles of the right knee are 176.48° and 165.06°, respectively, and the flexion of the right knee is not large; especially when the left foot touches the ground, the right leg is close to a straight line, indicating that the athlete's body is in a straight line. The posture is relatively good, the left foot is used as the grounding leg, the angle of the knee joint is reduced from 160.82° to 124.41°, and the left knee buffer angle is 36.40°. As the right leg swings to the ground, the left knee and left hip are slightly stretched, and the right knee and right hip are slightly flexed. This change is also reflected in the fact that the center of gravity changes from the direction of the horizontal speed at this stage. Move the left side of the body slightly to the right. Difficulty movements are different in the landing stage, and their joint parameters are also different. When the landing leg touches the ground, there is no significant difference in the maximum cushioning time, the degree of torsion of the shoulder and the hip is different, the relative rotation position of the shoulder and the hip is opposite, and the posture of the shoulders at the time of landing is different. In teaching, the landing leg and the end direction of the rotation are not the same; it is necessary to strengthen the strength training of the legs, to experience the force feeling of the different degrees of rotation of the shoulder joint and the hip joint, as well as the spatial perception ability, and take the initiative to actively land. The magnitude of the rear cushion and the coordination of the trunk and the limbs are used to avoid unnecessary damage during the landing phase.

1. Introduction

Wushu has rich cultural connotations. It is a traditional sports event that has been continuously created and gradually formed by countless sages of the Chinese nation in the course of thousands of years of historical evolution. It is an important part of China's traditional excellent historical culture [1]. As early as 1960s, China included martial arts as

a course in the physical education syllabus of primary and secondary schools. Social popularization can achieve the purpose of promoting the spirit of China's national traditional culture while promoting the effect of fitness [2]. With the development of Wushu, it now occupies a place in physical education in colleges and universities. Physical education majors in colleges and universities all have martial arts specialties. Students majoring in physical

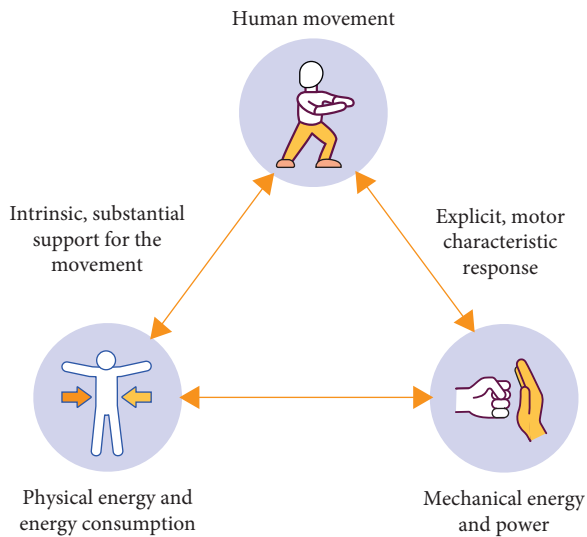


FIGURE 1: Research progress of sports biomechanics energetics and actions, such as simple jumping and flying.

education with higher skills and accomplishments choose one of the many sports (including martial arts) they have learned as their major. Students who choose Wushu as their major mainly learn simple Wushu routines, equipment, basic jumping movements, and Wushu theory and will mainly focus on Wushu teaching in primary and secondary schools in the future. At present, the analysis and research of high-difficulty movements in Wushu movements are the main direction of this research, thus ignoring the research on the basic movements [3]. For ordinary martial arts learners and enthusiasts with average physical fitness, most of them face these difficult martial arts' moves with an attitude of a dispensable attitude, and they are most exposed to the basics of martial arts moves in their learning and practice. Actions include simple jumping and flying. Figure 1 shows the progress in motion, biomechanics, and energetics. However, studies on such relatively simple and highly ornamental movements are rarely seen in the current research. The movement of "running and swaying the lotus 360° to land on one foot" is one of the basic jumping movements of martial arts, and it is also the movement learned by the martial arts students specializing in physical education [4]. This action is relatively difficult to master than other basic jumping action technical routes, but it is highly ornamental. There are a large number of studies at different levels in the research on Wushu technical movements, such as the research on the flying classes B- and C-level movements in Wushu routines, the research and analysis of a classic Taijiquan movement, and the analysis of a certain movement in Sanda.. Summarizing these studies, it is found that most of the technical movements studied and analyzed are highly difficult movements in competitive martial arts competitions, such as "flying the lotus 360° to lift the knees independently, swinging the lotus 540°, cyclone feet 720°, and spinner rotation of the body 360°;" there are few studies on the "run-up, swaying, and 360° single-leg landing" action.

2. Literature Review

Aiming at this research problem, Koryagina et al. obtained the characteristics of each joint angle, joint speed, force sequence, and other characteristics of the experimental subjects in difficult movements through three-dimensional kinematics analysis of the selected difficulty. Combined with the characteristics of sports mechanics, the dynamic parameters required in the process of Shoumin's superaction can be obtained, so as to analyze and study the results and provide a more regular and reasonable reference for the improvement and training of the difficult movements of the competition [5]. Rusdiana et al. analyzed Chinese outstanding competitive aerobics athletes through biomechanical research, obtained various kinematic parameters and data, obtained the parameters of athletes' movement techniques, obtained the laws of movement activities, and provided reference for actual training, judging the athletes' movement problems and the reasons for the problems, and put forward specific methods to solve the problems [6]. Keisuke et al. believe that difficult movements play a very important role in the complete set of competitive Taijiquan movements. The rules stipulate that a difficult movement should be selected, which determines not only the completeness of the set, but also the score and difficulty of the difficult movements which is an important factor in the score [7]. Rajkumar et al. discussed the characteristics of human body changes after aerobics exercise and the aspects of aerobics competition and training from the aspects of human physiology and anatomy [8]. da Silva Soares et al. also used biomechanics to dissect the perspective of body shaping and aerobic exercise [9]. A large number of documents reviewed by Biscarini et al. found that the current biomechanical research is mainly used in the analysis of human body structure and sports function, movement technology, sports injuries, planning and improvement of sports equipment, general fitness, and fitness guidance for special groups, etc. The proportion of research in this area is also increasing [10]. Perry et al. studied the mechanical characteristics of human activities and the general characteristics of movement changes and the science of sports equipment development [11]. Powell et al. pointed out that the current kinematic research methods of biomechanics mainly include camera and image analysis, infrared light point motion capture and analysis, electromagnetic induction motion capture, and analysis, among which three-dimensional camera and analysis methods have been widely used [12]. Hsiao et al. used the observation video method and the image analysis method to analyze the technical movements of the two research subjects. The width provides a reference in [13]. Lempke et al. conducted a biomechanical comparative analysis of five different levels of badminton players' backcourt smashing techniques by using three-dimensional camera measurement method. By capturing these reflective points, the obtained moving images are more vivid, which reduces the workload for subsequent moving image analysis [14]. The kinematics of aerobics movement decomposition based on the video tracking algorithm is discussed and analyzed. The feasibility

of the aerobics motion decomposition based on multi-motion target video tracking algorithm is summarized. The experiment concluded that at the beginning the right hip angle was 167.45°. As can be seen from the angles of both knees, the legs are relatively straight and remain in good position. When the jump contacts the ground, the difference between the two moments of the right hip angle is 29.8°. At this time, the upper body starts to bend, stretching the left muscle, so that the hip joint and shoulder joint form a larger rotation angle [15].

Based on the current research, this paper proposes a kinematic analysis of the difficult movements of competitive Tai Chi. Taking the difficult movements of the swirl group of competitive aerobics as the research object, this article takes the right leg as the swing leg and the left leg as the take-off leg when completing the difficult movement, as an example. The results show that, from the moment the left foot hits the ground to the moment of maximum cushioning, the angles of the right knee are 176.48° and 165.06°, respectively, and the flexion of the right knee is not large; especially, when the left foot touches the ground, the right leg is close to a straight line, indicating that the athlete's body is in a straight line. The posture is relatively good, the left foot is used as the grounding leg, the angle of the knee joint is reduced from 160.82° to 124.41°, and the left knee buffer angle is 36.40°. As the right leg swings to the ground, the left knee and left hip are slightly stretched, and the right knee and right hip are slightly flexed. This change is also reflected in the fact that the center of gravity changes from the direction of the horizontal speed at this stage. Move the left side of the body slightly to the right. Difficult movements are different in the landing stage, and their joint parameters are also different. When the landing leg touches the ground, there is no significant difference in the maximum cushioning time, the degree of torsion of the shoulder and the hip is different, and the relative rotation position of the shoulder and the hip is opposite, and the posture of the shoulders at the time of landing is different. In the teaching, the landing leg and the end direction of the rotation are not the same; it is necessary to strengthen the strength training of the legs, to experience the force feeling of the different degrees of rotation of the shoulder joint and the hip joint, as well as the spatial perception ability, and take the initiative to actively land. The magnitude of the rear cushion and the coordination of the trunk and the limbs are used to avoid unnecessary damage during the landing phase.

3. Methods

3.1. Research Objects. This paper takes the difficult movements of the swirl group of competitive aerobics as the research object.

3.2. Research Methods

3.2.1. Documentation Law. According to the research purpose and significance of this paper, through the CNKI retrieval platform, with the keywords of "competitive Taijiquan," "difficulty movement," "kinematics," and

"sports biomechanics," the literature related to the research since 2018 was searched. 26 representative works, consulting the relevant books in the library and literature database of Beijing Sports University, understand the current research status of the current related competitive aerobics projects, especially the kinematic analysis of difficult movement techniques, carefully study the relevant materials, and classify the collected materials. The classification, summary, and analysis provide a theoretical basis for the writing of the research content of this paper.

3.2.2. Interview Method. According to the research needs of this article, consult the coaches in the field of competitive Tai Chi on the basic movement structure, technical key points, matters that need attention, and main training methods of jumping. At the same time, experts in sports biomechanics were consulted about the shooting design, stage division of difficult movements, and kinematic parameter requirements in this study [16].

3.2.3. Experimental Method. Competitive Taijiquan athletes were selected as test subjects, males, 173 cm tall, 63 kg in weight at the time of the test, and had a training period of 15 years.

3.2.4. Data Collection. Test equipment: the experimental data collection was completed in the Taijiquan gymnasium of a comprehensive training hall of a sports university. An 8-lens infrared light spot high-speed motion capture system (QUALISYS-MCU500) was used to collect the kinematic data of the test object completing difficult movements, and the sampling frequency was 200 Hz.

Site preparation: before data collection begins, draw all the curtains on the test site to block unnecessary light spots, calibrate the test area, and place the 8 lenses of the infrared light spot high-speed motion capture system in the front, left, and rear of the test area. For the positions of the right and left front, left rear, right front, and right rear, adjust the angle and height of the lens, connect to the computer for multiple corrections, and eliminate the interference of excess light spots [17, 18].

Athlete preparation: athletes arrive at the test site in advance to prepare for warm-up activities and change into shooting clothes. Paste marker points according to the Hele-Hayes mannequin, completed by students majoring in sports biomechanics.

Infrared spot calibration: the athlete enters the test area and calibrates the infrared spot on his body.

Test process: after the athletes are ready, the testers issue the start password and collect data on the athletes completing the specified difficulty movements, each of which is completed 6 times; 3 referees on the scene will score the completion of each action, according to the referee's score. In each case, each action with the highest score is selected for later data processing [19].

TABLE 1: Lower limb angle parameters in the take-off stage.

Feature screen	Time	Hip joint		Knee joint		Ankle joint	
		Right	Left	Right	Left	Right	Left
Start time	0	163.84	128.85	168.88	178.1	109.3	137.5
Take-off leg landing moment	0.346	137.24	143.51	169.96	155.03	96.22	117.74
The minimum moment of the knee angle of the take-off leg	0.374	67.96	48.24	144.77	121.21	89.08	86.7
The lowest moment of the head	0.424	76.33	32.68	153.13	127.54	88.41	87.52
Moment of swinging leg off the ground	0.48	116.24	43.94	168.63	141.35	118.74	87.67
The moment when the take-off leg leaves the ground	0.664	153.88	124.72	165.76	157.95	145.65	125.25

3.2.5. *Division of Action Stages.* Due to different personal exercise habits when completing difficult movements, this paper takes the right leg as the swing leg and the left leg as the take-off leg when completing the difficult movements. The test object in this paper adopts the traditional three-step up-step method. The starting time of the take-off phase is consistent with the diagram. By consulting experts for the division of the difficult movement, and, according to the needs of the research, the two movement stages are equal. It is divided into three stages: take-off, air-to-air, and landing.

The specific division is as follows.

Take-off stage: it is divided into single-foot support, double-foot support, and single-leg extension stage. In this study, when taking three steps up, the moment when the athlete swings the leg to the highest center of gravity in the third step was taken as the starting moment, and the moment when the take-off leg kicked off the ground was taken as the end point, and the process was defined as the take-off stage. The single-leg support stage is from the starting time to the time when the take-off leg touches the ground, the double-foot support stage is from the time when the take-off leg touches the ground to the time when the swing leg leaves the ground, and the single-leg stretch stage is from the time when the swing leg leaves the ground to the time when the take-off leg leaves the ground [20].

Flying stage: it is divided into rising and falling stages. The flying stage refers to the moment when the take-off leg leaves the ground to the moment when one foot touches the ground. The highest moment in the sky is the cutting point, and it is divided into the rising stage and the falling stage. Landing stage refers to the process in which the athlete is swinging his legs to the ground with both feet when one foot hits the ground.

3.2.6. *Data Processing.* The research data is processed and analyzed through the software in the Qualisys system to obtain the kinematic parameters required for the research, and the Cortex software is used to derive the body center of gravity parameters and the Euler angle of the torso relative to the pelvis [21].

3.3. *Mathematical Statistics.* According to the actual needs of the research, the data obtained are summarized, sorted, classified, calculated, and charted using Excel software.

3.4. *Comparative Analysis Method.* By analyzing the kinematic parameters of the athlete's swirl and swivel 360°

difficult movements and comparing the technical characteristics of the two movements at the same stage, the similarities and differences in each link of the two difficult movements were found out [22].

4. Results and Analysis

4.1. Kinematics Analysis of Difficult Movements in the Take-Off Stage

4.1.1. Kinematic Analysis of Joint Parameters of Lower Limbs.

It can be seen from Table 1 that the right hip is fully extended, the right hip joint angle is 163.84°, and the left hip joint angle is 128.85°. It can also be seen from the angle of the two knee joints that the legs are relatively straight and maintain a good body posture. When the take-off leg touches the ground, the difference between the right hip angles is 26.5°, and the left hip angle difference is -14.65°; that is, the right hip angle decreases and the left hip angle increases [23, 24]. The right hip angle decreases, indicating that the upper body begins to bend down while the upper body turns to the right, the left hip continues to abduct, and its value increases. When the left external oblique muscle is elongated, the shoulder-hip torsion angle also increases accordingly.

In the take-off stage, the upper body is also bent down and folded, and the hip joint angle first decreases and then increases. The left hip joint is flexed to a minimum value of 32.68° at the lowest moment of the head. In the subsequent hip extension process, the hip angle changes greatly; especially when the take-off leg leaves the ground, the right hip angle is 153.88°, and the left hip angle is 124.72°. Judging from the knee angle data, the minimum flexion degree of the left knee is 121.21°, while the hip flexion is more obvious at this moment, and the corresponding ankle joint angle is close to 90°, indicating that the knee flexion and squatting range is small during the take-off stage, mainly the upper body trunk. Movement is dominant. Combined with the angle of the hip and knee joints when the take-off leg is off the ground, the range of flexion of the hip and knee is small, which is conducive to the rotation of the body on the same longitudinal axis during the flight.

4.1.2. Kinematics Analysis of the Trunk Action Link.

According to the definition of the positive and negative values of the shoulder-hip torsion angle in this paper, the positive value is the left rotation state of the shoulder relative to the hip, and the negative value is the right rotation state.

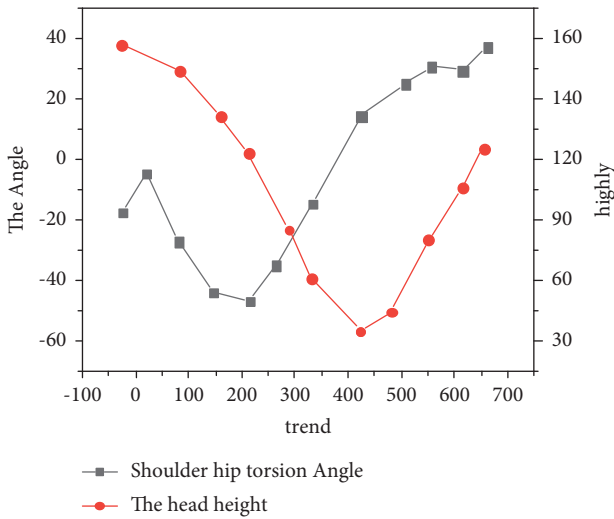


FIGURE 2: Shoulder-hip torsion angle and head height-time curve in take-off stage. It also means that the rotator rotates 360° at the lowest moment of the head to turn to the front and left of the body.

In the take-off stage, the amplitude of the shoulder and hip rotation also increases first, then decreases, and then increases, and the shoulder joint turns from right to left relatively to the hip joint.

It can be seen from Figure 2 that the shoulders are twisted to the right of the hips before the take-off and the reverse rotation of the hips and shoulders reaches the maximum value of -47.32° , which corresponds to the moment when the take-off leg touches the ground. With the movement of the upper body during the take-off phase, the shoulders are rotated to the left, reaching the maximum value of 37.75° ; that is, when the shoulders and hips rotate at the same time, the shoulders are rotated 85.06° relatively to the hips. Combined with the change in the height of the head, the head movement curve first falls and then rises. The lowest moment of the head is after the rotation angle of the shoulder and hip is 0° , that is, the position in front of the body to the left. It can be seen from the data of the intersection of the vertical dotted line and the two curves in the figure that the height of the head at the lowest moment of the head is 25.97 cm and the corresponding torsion angle of the shoulder and hip is 15.32° . It also means that the rotator rotates 360° at the lowest moment of the head to turn to the front and left of the body.

Through the parameters of the torso relative to the pelvis torsion, the relative position of the torso space can be reflected more three-dimensionally. As shown in Table 2, when the take-off leg hits the ground, the trunk is flexed forward to -160.38° , and the lateral flexion is flexed from the original left to the right to -7.31° . At the same time, the trunk turns right to -20.85° , which elongates the left external oblique muscle. When the buffer reaches the minimum knee angle of the take-off leg, the trunk has been bent forward to the minimum value of -123.34° , but in fact the forward flexion is greater, indicating that the pelvis is in a forward tilted state at this time. At the lowest moment of the head, the shoulders and hips are almost parallel, and only 1.28° left.

At the moment of taking off and leaving the ground, the trunk turned to the left to a maximum value of 21.76° , and the left area continued to increase to 30.79° . The trunk moved from flexion to extension, and the angle was 179.00° , which almost coincided with the vertical axis of the body, indicating that the rotator rotates. The body 360° has a small upward lift when taking off, and it is mainly for the rotation during the flight phase to keep close to its vertical axis.

4.1.3. Kinematics Analysis of the Single-Leg Extension Stage.

In this paper, the shoulder-foot torsion angle is defined as the angle of the line between the shoulders and the left foot in the horizontal plane, and the hip-foot torsion angle is the angle of the line between the two hips and the longitudinal axis of the left foot in the horizontal plane. In the single-leg extension stage, the shoulder-foot torsion angle and the hip-foot torsion angle continued to increase, and the trends were similar; that is, the shoulder and hip joints were twisting synchronously. When the rotation reaches the maximum value and then falls back, the shoulder-foot torsion angle is the same as the maximum hip-foot torsion angle. At this moment, the athlete's upper torso has rotated to the maximum in the horizontal plane. The shoulder-foot torsion angle is the line connecting the shoulders and the left foot in the horizontal plane. The maximum value of the included angle is 136.98° , and the maximum value of the hip-foot torsion angle, that is, the angle of the line connecting the two hips and the longitudinal axis of the left foot in the horizontal plane, is 105.03° . Due to the limitation of the physiological structure of the hip joint, the torsion amplitude is smaller than that of the shoulder joint.

After swinging the leg off the ground in the single-leg extension stage (Figure 3), the projection angle of the right hip on the horizontal plane has a maximum value and is close to 180° , indicating that the projections of the right shoulder, hip, and knee on the knee angular velocity show an upward trend after reaching the minimum value of $127.7^\circ/\text{s}$; that is to say, the minimum value corresponding to the left knee angular velocity is the timing of single-leg take-off when the rotor rotates 360° . In addition, the right hip angle at the time of single-leg extension was 139.88° . Although the hip was not fully extended, it can be seen from the curve of the right hip angle that, during the single-leg extension stage, the right hip angle continued to increase and the maximum value was about 170° ; it means that the upper body torso and the right leg are close to the same-vertical axis, which is conducive to the rotation of the body around its own vertical axis in the subsequent flight stage.

4.2. Kinematics Analysis of the Flight Stage.

In the flight stage, the rotation is mainly driven by the shoulder joint. According to the angle between the shoulders and the hips and the horizontal plane in the original data, combined with the height of the shoulder and hip joints, the rotation of the hip joint at the characteristic moment can better reflect the flight stage. Therefore, in order to facilitate the study, this paper selects the angle of the connection line between the two hip joints and the ground, that is, the hip inclination

TABLE 2: Torsion angle parameters of the trunk relative to the pelvis during the take-off stage.

Feature screen	Time (s)	Sagittal plane (°)	Frontal plane (°)	Level (°)
Start time	0	148.97	10.80	21.29
Take-off leg landing moment	0.346	-160.38	-7.31	-20.85
The minimum moment of the knee angle of the take-off leg	0.374	-123.34	6.70	-4.03
The lowest moment of the head	0.424	-126.51	10.29	1.28
Moment of swinging leg off the ground	0.48	-137.14	19.84	2.84
The moment when the take-off leg leaves the ground	0.664	179.00	30.79	21.76

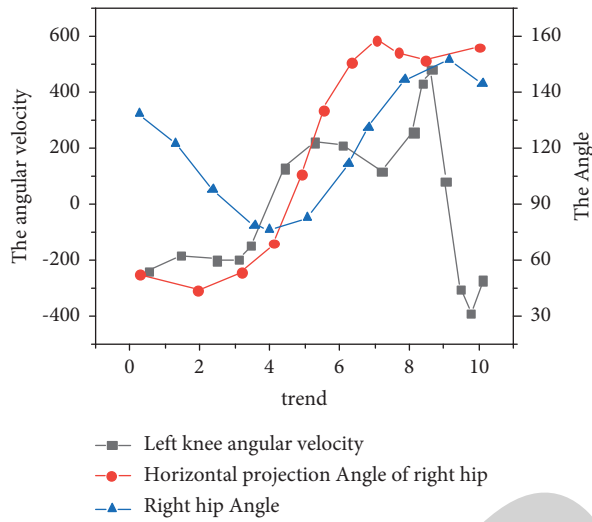


FIGURE 3: Left knee angular velocity, right hip horizontal plane projection angle, and right hip angle-time curve during single-leg extension. It means that the upper body torso and the right leg are close to the same-vertical axis, which is conducive to the rotation of the body around its own vertical axis in the subsequent flight stage.

angle as the parameter. In addition, due to the rotation process of the vertical plane of the hip joint, there will be a certain deviation, but the data deviation is relatively and highly tiny, so the maximum value in each revolution is defined as a special moment. In this paper, after the jump, the first time when the line between the two hips is parallel to the ground is defined as the moment when the hip joint rotates 0° , and there are four characteristic moments when the hip joint rotates 0° , 90° , 180° , and 270° relatively to the ground after taking off to analyze the state of the body in the air.

According to the data in Table 3, the duration of each 90° rotation of the athlete is 0.11s, 0.09s, and 0.125s, respectively. It can be seen that the rotation speed in the air is extremely fast, and their body posture is also changing all the time. Spread your legs apart, keep your body parallel to the ground, and turn your body 360° . The following is an analysis of the flight stage based on the rules and standards, combined with the side and top views of the four characteristic moments. Combined with the data in Table 3, at the beginning of the take-off and after the take-off, since the shoulder joint has begun to rotate during the take-off and extension stage, the shoulder and hip twist is the largest at 4 moments, which is 60.13° . Through the early rotation of the shoulder joint, effectively drive the body to rotate, increase the angular speed of rotation, and reduce exercise time. It

can be seen from the table that the upper body and the right leg move towards each other and are obviously higher than the horizontal plane and the angle of the legs is 73.93° .

4.3. Kinematic Analysis of Landing Stage. During the flight stage, the shoulders and hips are mainly driven by the rotation. When preparing to land, the right leg and the torso should be rotated as much as possible while maintaining a horizontal posture. At the same time, the left leg will actively move to the ground to prepare for landing, and the arms will gradually expand. In the landing stage, after the left foot hits the ground, at the moment of landing, the body is almost facing the ground. During the transition from landing on one foot to landing on both feet, since the left foot hits the ground first, and the overall speed of the body in the direction of the horizontal plane is on the right side of the body position, the rotation speed in the air is relatively large. The right leg also continues to swing in the direction of motion while moving downward. The right leg continues to swing and arc down in the direction of the horizontal plane speed. It is shorter and has a higher movement speed, which increases the load of the landing leg accordingly. The upper body should not be lifted too early to ensure the stability of the center of gravity.

From the data in Table 4, at the moment when the left foot touches the ground, the torsion angle of the shoulder and hip is 18.2° , and the relative angle of the line connecting the shoulders and the hips is much smaller than that in the flying stage. The hip joint gradually returns to the same plane. At the moment when the left foot touches the ground, the left hip joint is 103.98° , slightly larger than 90° . This is the angle between the left leg and the horizontal plane at this moment, which is the upward direction of the landing. The degree of flexion and extension of the body trunk is related, and, from the video screen, it has a greater correlation with the direction when landing. From the moment when the left foot hits the ground to the moment of maximum cushioning, the angles of the right knee joint are 176.48° and 165.06° , respectively, and the flexion of the right knee is not large; especially when the left foot touches the ground, the right leg is close to a straight line, indicating that the athlete's body posture is relatively ok, the left foot is used as the grounding leg, the angle of the knee joint is reduced from 160.82° to 124.41° , and the left knee buffer angle is 36.40° . As the right leg swings to the ground, the left knee and left hip are slightly stretched, and the right knee and right hip are slightly flexed. This change is also reflected in the fact that the center of gravity changes with the direction of the

TABLE 3: Rotation parameters of the hip joint at four moments in the flight stage.

Feature screen	Duration	Split angle	The angle between the thigh and the horizontal plane		Shoulder torsion angle
			Right	Left	
			Hip rotation 0° (rise in the air)	0	
Rotate the hip joint 90° (in the air)	0.10	40.23	1.44	6.41	56.67
Hip rotation 180° (highest in the air)	0.08	49.36	33.51	-14.14	46.43
Hip rotation 270° (flying down)	0.124	45.91	10.10	32.92	25.28

TABLE 4: Joint parameters in landing stage.

Feature screen	Hip angle		Knee angle		Shoulder torsion angle
	Right	Left	Right	Left	
The moment when the left foot touches the ground	155.36	103.98	176.48	160.82	18.2
Maximum buffer time	111.91	80.14	165.06	124.41	21.0
The moment your feet touch the ground	97.92	89.52	155.94	137.83	10.7

horizontal speed at this stage. Move the left side of the body slightly to the right.

In general, the difficult movements have different landing legs in the landing stage, and their joint parameters are also different. When the landing leg touches the ground, there is no significant difference in the maximum cushioning time and the degree of torsion of the shoulder, and the hip is different, and the relative rotation position of the shoulder and the hip is opposite, and the posture of the shoulders at the time of landing is different. In teaching, the rotation direction of the landing leg is different from the rotation direction of the upper body. It is necessary to strengthen the leg strength training to experience the force sense of the shoulder joint and hip joint at different degrees of rotation, as well as the spatial perception ability. The magnitude of the rear cushion and the coordination of the trunk and the limbs are considered to avoid unnecessary damage during the landing phase.

5. Conclusion

This paper proposes a sports biomechanical analysis of jumping difficult movements in Tai Chi. Using the literature method, interview method, experimental method, etc., with the help of infrared light spot high-speed motion capture system, the kinematic data of athletes completing difficult movements is collected, the technical characteristics of difficult movements are analyzed, and the key technical characteristics of this group of difficult movements are explored to promote Tai Chi diversified development of boxing. In the take-off stage, the hip is also mainly flexed. When the single foot is extended, the projection angle of the horizontal plane of the right hip tends to be a straight line, and the right hip angle is 140°. It is beneficial to the rotation around its own vertical axis in the subsequent flight stage. At the beginning of the flight, the angular velocity is increased by the prerotation of the shoulder and hip joints, and the rotation radius is reduced and the kinetic energy loss is reduced with the approach of the limbs to the vertical axis of

the body; the torsion of the shoulder and hip is relatively large in the stage of flight and ascent, and the rotation is dominated by the shoulder landing. During the stage, the load on the grounding leg is relatively large, and the upper body should be avoided to be lifted prematurely. In the future, in the practice of strengthening students' basic skills, solid basic skills are the basis for improving the quality of technical movements. In view of the unreasonable athlete's approach route and take-off foot abduction angle, it is explained in a targeted manner, and repeated training can strengthen the athlete's movement awareness and improve the movement quality.

Data Availability

The data used to support the findings of this study can be obtained from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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