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Retraction

Retracted: Analysis and Comparison of Motion Biomechanics Characteristics of Squat Jump and Half-Squat Jump

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1].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

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[1] M. Zhao and J. Zhang, "Analysis and Comparison of Motion Biomechanics Characteristics of Squat Jump and Half-Squat Jump," *Mobile Information Systems*, vol. 2022, Article ID 4304216, 7 pages, 2022.

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Research Article

Analysis and Comparison of Motion Biomechanics Characteristics of Squat Jump and Half-Squat Jump

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In order to study the biomechanical characteristics of squat jump and half-squat jump, analysis and comparison were made. This paper tests and analyzes the kinematics and dynamics of 63 young men's squat jump, and synchronously collects the kinematics and dynamics data of subjects in the process of weight-bearing squat, in-situ free jump, and high platform landing. The experimental results showed that there was significant difference in knee joint angle at the time of toe off ($P < 0.05$), and there was significant difference in ankle joint angle at the time of toe off ($P < 0.05$). The time law of squat jump and semi squat jump in vertical jump was the same. In vertical jump, the reaction time law of squat jump and semi squat jump is the same, and the recovery standing time is the longest, followed by the take-off time and reaction time. The two vertical jump methods have no effect on the height, time, and speed of exercise take-off.

1. Introduction

Squatting is the most common form of lower limb movement in daily life and sports. It can be generally divided into two stages: squatting and pedaling. The squatting stage is mainly medullary joint flexion, knee joint flexion, and pedal joint dorsiflexion; the pedal extension stage is skeleton joint extension, knee joint extension, and pedal joint extension. When jumping to the ground, the squat stage can also be called the buffer stage, which is manifested in passive flexion of the skeleton and knee joints, and the back flexion of the manic joint is also passive. For example, the weight-bearing squat, deep jump, and vertical jump in physical training all include this form of movement. How to improve sports performance and prevent injury are two research hotspots in today's sports field. Squatting, as the basic action of load squatting and jumping, has attracted more and more attention of the researchers [1]. Correct movements may reduce the risk of knee and back injuries during squatting. Some studies believe that the correct squat technique includes keeping the lower leg as upright as possible in order to reduce the shear force of the knee joint, which means that the knee joint does not exceed the toe. In the study, this squat form that restricts the knee joint not to exceed the toe is called "restricted squat". Modern physical training theory believes that whether it is weight-bearing squatting exercise or jumping take-off and landing, the knee joint should not exceed the toe, and ensure that the lower leg is perpendicular to the ground as much as possible, which can avoid unnecessary pressure on the knee joint and reduce the injury of the knee joint. Some studies have suggested that squatting with the knee joint not exceeding the toe may also improve the effect of strength training. Biomechanics is a new frontier discipline of modern mechanics, which plays an important basic role in the field of biology and medical engineering. Biomechanics is based on the original qualitative description and Empirical Study of organisms, combined with the relevant theories and methods of modern mechanics, to quantitatively study the structure, function, and stress movement of organisms, and finally serves biotechnology and biomedical engineering [2]. The research scope of biomechanics is very wide, ranging from the whole organism to bones, blood, organs, and so on. Among them, orthopaedic biomechanics is a very important branch. It applies the relevant principles of mechanics to the research field of orthopaedic medicine. In the field of orthopaedic medicine, the biomechanical research of knee joint has always been the focus of orthopaedic medicine research.

Great progress has been made in the research ability and level of sports biomechanics in China. In the field of applied research, especially the technical diagnosis of elite athletes, we have relatively perfect detection conditions, and have accumulated rich experimental data, including creative research results, which have been widely praised by the competitive sports industry (Figure 1). Comparatively speaking, the accumulation of theoretical research and research methods of sports biomechanics is relatively small, and the research content is not rich or deep enough. The relatively weak foundation of this theory and method has become the main factor restricting the development of sports biomechanics in China. At present, the research object of sports biomechanics is the internal movement system of human body and the overall mechanical movement characteristics of human body [3]. In order to facilitate research, the key of sports biomechanics theory and method is to establish a mechanical model of human motion to describe motion. There are generally two methods. The first method is the research method of human system simulation. The second method is to establish the mechanical model by using the theory of multi rigid body system dynamics. In the research of sports biomechanics, the motion of most mechanical systems is controlled by Newton's law of motion, so the established models are expressed in the mathematical form of Newton's mechanical system [4].

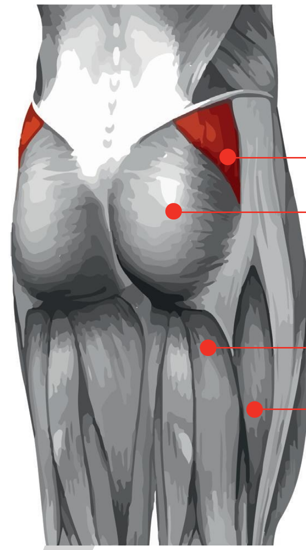

Figure 1: The relatively weak foundation of this theory and method has become the main factor restricting the development of sports biomechanics in China.

2. Literature Review

Crossley et al. found that when the weight-bearing squat is parallel to the thigh and the ground, the limited negative claw probe squat increases the forward inclination angle of the trunk. He believes that although the limited weight-bearing squat can reduce the pressure of the knee joint, it will transfer this pressure to the medullary joint and the lower back [5]. Villa et al. found that when the knee does not exceed the toe, the curvature of the lumbar spine is significantly less than that when the knee exceeds the toe [6]. This is consistent with the research results of Trinh et al.. The curvature of the thoracic spine changes little. When limiting the movement of the knee joint, the increase of the angle between the pelvis and the lumbar spine leads to the increase of the forward tilt angle of the torso. We have reason to believe that the pressure exerted on the lumbar spine and the lower lumbar spine will increase. List and others found that in the process of weight-bearing squatting, the curvature of lumbar spine and thoracic spine decreased during squatting, while in the process of road extension, the curvature of lumbar spine and thoracic spine gradually increased [7]. Zhang et al. found that the angle between lumbar vertebrae and thoracic vertebrae of athletes with restricted squat is larger than that of athletes with restricted squat, and the most human joint angle between lumbar vertebrae and thoracic vertebrae occurs when 25% of body weight is loaded. In this study, the thoracic curvature can be compared with the unrestricted squat, while the lumbar curvature has no difference in the two cases, and it is confirmed that there is a direct correlation between the curvature change of the spine and the load, and the lumbar curvature decreases with the increase of the load [8]. Muller et al. believe that in the process of weight-bearing squat, the barbell is placed above the shoulder blade, the weight of the barbell is directly transmitted through the spine, and the load on the lower back is determined by the weight of the barbell and the forward inclination angle of the trunk [9]. Runciman et al. limited squat (knee joint does not exceed toe) is required by most coaches to be applied in various trainings. Many experts explain that this can reduce the load on the knee joint. Weight squatting is a process of flexion and extension of all joints of lower limbs. The purpose is to increase muscle strength and protect the joints. The correct squatting method should not be at the cost of protecting one joint and causing damage to another joint, or causing damage to other parts in order to stimulate one part [10]. Liao et al. used an experimental device to fix the femur to load the quadriceps femoris and measure the movement trajectory of the skeleton. However, this experiment does not load human gravity on the femur, so the experimental device has defects and needs to be improved [11]. The experimental device of Jayedi et al. was improved on the five axis KKS knee simulator. The experimental device can load three bundles of muscles. However, in his experiment, both femur and tibia were osteotomized, and human physiological load was not loaded at the femoral head [12].

3. Research Method

In this experiment, 63 ordinary young male college students are selected as the research objects. They are required to be healthy, have no injuries in recent two months, have sound limbs, and no old diseases. The basic information is shown in Table 1.

3.1. Experimental Method. In this study, dynamics and kinematics were tested simultaneously. The KY three-dimensional force measuring platform developed by Hefei Institute of intelligence, Chinese Academy of Sciences was used for the dynamic test, and the frequency was 500 Hz/s. The body weight of the subjects was deducted in the dynamic analysis; The JVC9800 camera is used for two-dimensional camera in kinematics test. The shooting speed is 50FPS and the shooting distance is 10 m. The main optical axis of the camera is perpendicular to the motion plane [13]. The video analysis software adopts dartfish5 0. All tests are completed within one week, starting at 9 : 30 and ending at 11 : 30 every morning. Each subject's swing arm CMJ and non swing arm CMJ were tested three times, and the one with the most coordinated action was selected during the analysis. Requirements for CMJ test of swing arm: the subject stands vertically on the force measuring platform, his legs are the same width as his shoulder, and the initial action is both arms. Lift vertically, swing your arms freely, squat down, and take-off vertically. CMJ test requirements without arm swing: the subjects cross their hands behind their backs, open their legs the same width as their shoulders, start to squat freely, and take-off vertically. The description method of quantitative data is mean ± standard deviation. The comparative analysis of swing arm and non swing arm adopts paired sample *t*-test. The significance level is 0.05 and the very significance level is 0.01 [14].

3.2. Result Analysis. The moment of maximum knee flexion angle is defined as the dividing point between squatting stage and pedaling stage. The peak flexion angle of hip joint ($P = 0.046$), the peak flexion angle of knee joint ($P < 0.001$), the peak flexion angle of ankle joint ($P < 0.001$), and the forward inclination angle of trunk ($P < 0.001$) have significant differences in two different movements (Table 2). The peak flexion angle of knee joint and forward inclination angle of trunk in restricted squat are greater than those in unrestricted squat, and the peak flexion angle of hip joint, back flexion angle of ankle, and foot unrestricted squat are greater than those in the restricted squat [15].

At the time of maximum knee flexion, both restricted and unrestricted squats showed significant differences between hip flexion and flexion ($P = 0.048$) and ankle dorsiflexion ($P < 0.001$). The difference (Figure 2), the restricted squat hip flexion angle is greater than the unrestricted squat [16], while the restricted squat ankle dorsiflexion angle is smaller than the unrestricted squat.

The peak values of hip extension moment ($P = 0.023$), knee extension moment ($P = 0.003$), ankle plantar flexion moment ($P < 0.001$), and knee valgus moment ($P = 0.028$) have significant differences between the two different squats (Table 3). Except that the peak value of hip extension moment of restricted squat is greater than that of unrestricted squat [17], the peak value of knee extension moment, ankle plantar flexion moment, and knee valgus moment are greater than that of unrestricted squat.

At the maximum moment of knee flexion, there were significant differences between the two different squatting

Table 1: Basic information of subjects.

Index	Height (cm)	Body weight (kg)	Age (year)
Numerical value	172.5 ± 3.1	75.6 ± 2.6	30.5 ± 2.1

Table 2: Kinematic parameters of lower limb joints and trunk forward inclination angle during two squat modes.

Angle parameter	Restricted squat	Unrestricted squat	P value
Peak hip flexion angle	99.6 ± 6.3	96.5 ± 9.3	0.046^*
Peak knee flexion angle	106.5 ± 9.5	115.3 ± 10.6	$< 0.001^*$
Peak ankle flexion angle	101.8 ± 2.6	111.5 ± 2.0	$< 0.001^*$
Torso forward tilt angle	46.8 ± 2.6	46.5 ± 3.2	$< 0.001^*$

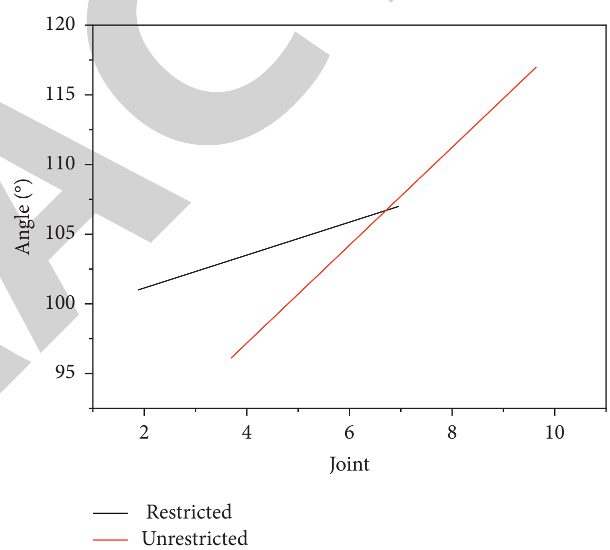

Figure 2: Hip and ankle angles at the peak of knee flexion angle the restricted squat hip flexion angle is greater than the unrestricted squat.

movements in terms of hip joint extension ($P < 0.01$), Teng joint extension (0.01), falling joint flexion torque, and knee valgus torque (0.02) (Figure 3). Except that the peak value of indigo joint extension moment of restricted squat is higher than that of unrestricted squat [18], the peak value of Teng joint extension moment, ankle plantar flexion moment, and Teng joint valgus moment are higher than that of restricted squat.

The jumping height of swing arm CMJ is about 8.5% higher than that of non swing arm. In the squat buffer stage, there was no difference in the total length of swing arm CMJ and no swing arm. However, compared with the non swing arm CMJ, the swing arm CMJ takes a shorter time in the acceleration squat stage and a longer time in the buffer stage. In the buffer stage, the swing arm CMJ has an o-point platform area. Starting from o point, the arm swings back and up from the vertical state, and the confrontation

Table 3: Lower limb joint torque (BW*BH) during two squats.

Torque parameters	Restricted squat	Unrestricted squat	P value
Peak value of hip extension moment	0.1324 ± 0.0268	0.0135 ± 0.0298	0.023*
Peak value of knee extension moment	0.0866 ± 0.0154	0.0998 ± 0.0148	0.003*
Peak ankle flexion moment	0.0430 ± 0.0132	0.0668 ± 0.0135	< 0.001*
Peak torque of knee valgus	0.0294 ± 0.0136	0.0326 ± 0.0168	0.028*

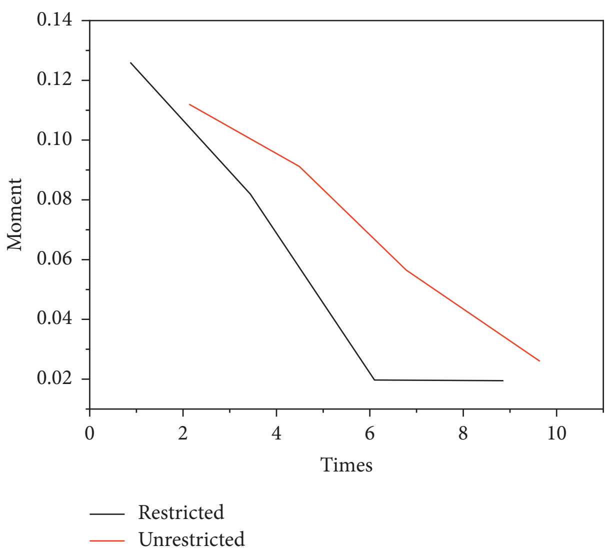

Figure 3: Lower limb joint dynamic parameters at the peak of knee flexion angle The impulse of CMJ of swing arm is larger than that of non swing arm in the middle and late stage of pedal extension.

between inertia moment, weight moment, reaction moment, and muscle extension moment prolongs the buffer time. In the stage of pedaling and stretching, the time of swinging arm CMJ is longer than that without swinging arm, which is mainly reflected in the middle and late stage of pedaling and stretching. At the maximum buffer moment, all joint angles reach the minimum value. During arm swing, the "compression" degree of hip and knee joints is lower than that without arm swing, and the support reaction force is also less than that without arm swing, which is conducive to the pedal extension moment to overcome the resistance moment and accelerate the pedal extension quickly. The impulse of CMJ of swing arm is larger than that of non swing arm in the middle and late stage of pedal extension. At the initial stage of pedaling and stretching, the impulse of the vertical jump of the swing arm is less than that of the non swing arm due to the effect of accelerating the downward swing arm [19].

From Figure 3, compared with the unrestricted squat, the limited squat has a larger peak value of hip flexion angle ($P = 0.029$), the lowest height of center of gravity ($P < 0.001$), a smaller peak value of knee flexion angle ($P < 0.001$), the peak value of ankle dorsiflexion angle ($P < 0.001$), the rise range of center of gravity during pedaling and stretching ($P < 0.001$), and pedaling and stretching time ($P < 0.001$). However, there was no significant difference in the maximum height of the center of gravity ($P = 0.205$) and the rising range of the center of gravity during the lifting process ($P = 0.366$) (Table 4).

4. Discussion

The back flexion angle of ankle joint at the maximum moment of knee flexion in restricted squat is less than that in unrestricted squat, which shows that the forward movement of knee joint in the two movements is different, which meets the experimental design and requirements. The results show that the limited squat has a smaller knee flexion angle than the unrestricted squat; smaller ankle dorsiflexion angle: larger hip flexion angle and larger trunk anteversion angle [20], which proves that limiting the forward movement of knee joint will lead to the change of kinematic indexes of lower limb knee joint and hip joint. During the limited squat, the limited forward movement of the knee joint will increase the back flexion angle of the ankle joint and reduce the forward inclination of the lower leg. Therefore, in order to prevent the body from leaning back, it will inevitably increase the flexion degree of the hip joint and the forward inclination degree of the trunk, so as to ensure the stability of the body in the fore-and-aft direction and ensure the proper position of the pressure center on the foot support surface. Moreover, the study also pointed out that additional load (0% BW, 25% BW, and 50% BW) will reduce the curvature of the lumbar spine. With the increase of load, the curvature of the lumbar spine will decrease, and the curvature of the thoracic spine of the limited squat is greater. When squatting to the lowest point, the trunk is in a forward leaning state. The lower curvature of the lumbar spine means that the lumbar spine is closer to a straight line. At this time, the trunk is more forward leaning, and the increased curvature of the thoracic spine means that the forward flexion of the thoracic spine is more obvious, further increasing the forward leaning angle of the trunk [21, 22]. In the process of weight-bearing squat, the barbell is placed above the shoulder blades, and the weight of the barbell is directly transmitted through the spine. The load on the lower back is determined by the weight of the barbell and the forward inclination angle of the trunk. From the anatomical structure of the human back muscles and spine, we can know that when the human trunk starts to lean forward, the muscles that extend the spine (erector spinalis) will contract to keep the body balanced. Therefore, when the trunk anteversion increases, the load on the back muscles will also increase. And some studies have shown that with the increase of trunk forward tilt angle, the erector spinalis muscle will stop working at a certain angle. At this time, in order to balance its own weight and the gravity generated by heavy objects, the non muscle tissues of the back, such as the fascia and belt of the waist and back, will bear these weights, so their risk of injury is greatly increased. It was found that when L4-5 segments of intervertebral disc pressure were in upright

Table 4: Kinematic parameters during in-situ vertical jump in two squat modes.

Kinematic parameter	Restricted squat	Unrestricted squat	P value
Peak hip flexion angle (°)	94.3 ± 11.2	91.3 ± 13.6	0.029*
Peak knee flexion angle (°)	86.3 ± 13.5	116.8 ± 13.5	< 0.001*
Peak ankle flexion angle (°)	103.6 ± 3.9	116.3 ± 3.6	< 0.001*
Pedal extension time (ms)	239.84 ± 56.35	306.35 ± 42.68	< 0.001*

position, the intervertebral disc pressure was the lowest. With the gradual increase of the flexion angle of the lower lumbar spine, the intervertebral disc pressure increases significantly [23].

In the process of squat jump, although the flexion angle of the hip joint increases in the restricted vertical jump, the peak value of the extension moment of the hip joint and the work done by the hip joint do not increase. According to the analysis of the reasons, it may be caused by the shortening of the pedal extension time. Although the knee and ankle joints of unrestricted vertical jump do more work, the peak height of center of gravity is no different from that of the restricted vertical jump. This is because the unrestricted squat is relatively deep. Although the lower limbs do more work in the process of pedaling and stretching, the extra work makes up for the difference in the squatting distance between unrestricted vertical jump and restricted vertical jump. Observing the initial vertical jump data, it is found that there is no difference between different subjects in the two actions, but the vertical jump ability reflected by different subjects in different actions is different, so there is no significant difference from the t-test results of paired samples [24]. Analyzing the reasons, the difference of vertical jump ability under the two different squatting situations may be caused by the subjects' own vertical jump habits and the different muscle strength and joint work proportion of each joint.

When an elastic body is subjected to an external force in an equilibrium state, the deformation and stress and strain of the elastic body respond to the action of the external force. During the whole process, the external force field releases the external force potential energy, and the elastic body stores and changes its properties. There are three energy representations for elastic problems: external force work, strain energy, and potential energy.

4.1. External Force Work. For any elastic body, it is subjected to the joint external force of the body force and its surface force [25], and the external force does work on its corresponding displacement, respectively. In the whole process, the total external force work is (1):

$$W = \int_{\Omega} (X\mu + Y_V + Z_{\omega}) \mathrm{d}\Omega + \int_{\Gamma} (\overline{X}\mu + \overline{Y}_V + \overline{Z}_{\omega}) \mathrm{d}\Gamma. \quad (1)$$

4.2. Strain Energy. The stress and strain of any micro-hexahedral element in the elastomer can be expressed as (2) and (3):

$$\sigma = \left[\sigma_x \ \ \sigma_y \ \ \sigma_x \ \ \tau_{xy} \ \ \tau_{yz} \right]. \quad (2)$$

$$\sigma = \left[\varepsilon_x \ \ \varepsilon_y \ \ \varepsilon_x \ \ \gamma_{xy} \ \ \gamma_{yz} \right]. \quad (3)$$

Without considering the initial stress and strain, the strain energy per unit volume of the elastomer is expressed as (4):

$$\begin{aligned} U &= \frac{1}{2}\varepsilon^T \\ \sigma &= \frac{1}{2}\varepsilon^T \\ D\varepsilon &= \frac{1}{2}\sigma^T D^{-1}\sigma. \end{aligned} \quad (4)$$

If considering the initial stress σ_0 and the initial strain generated by the mechanical constraints and temperature changes of system. 0 exists at the same time, and the relationship between stress and strain is (5):

$$\sigma = D(\varepsilon - \varepsilon_1) + \sigma_0 = D\varepsilon - D\varepsilon_1 + \sigma_0. \quad (5)$$

Then, the strain energy per unit volume can be expressed as (6):

$$U = \frac{1}{2}\varepsilon^T D\varepsilon - \varepsilon^T D\sigma_1 + \varepsilon^T \sigma_1. \quad (6)$$

Then, the total strain energy stored in the elastic body can be expressed in volume fraction, namely (7):

$$\overline{U} = \int_{\Omega} \overline{U} \mathrm{d}\Omega = \int_{\Omega} \left(\frac{1}{2}\varepsilon^T D\varepsilon - \varepsilon^T D\varepsilon_1 + \varepsilon^T \sigma_0 \right). \quad (7)$$

According to the external force work and strain energy of the elastic object, the system potential energy is defined as the sum of the external force potential energy and strain energy, namely (8):

$$\prod = U - W. \quad (8)$$

When an elastic object in equilibrium is subjected to an external force, any tiny virtual displacement allowed by the conditional constraints occurs, and the total work done by the external force on the virtual displacement is equal to the total virtual work generated in the object. That is (9):

$$\delta U = \delta W. \quad (9)$$

The virtual work principle matrix form of an object can be expressed as (10):

$$\delta d^T F = \int_{\Omega} \delta\varepsilon^T \sigma \mathrm{d}\Omega. \qquad (10)$$

5. Conclusion

The results showed that there was no significant difference between the two jumps in the time of taking off ($P > 0.05$), and there was no significant difference between the two jumps in the time of recovering from standing ($P > 0.05$); Spatial parameters: there was no significant difference between CMJ jump and SQJ jump in the proportion of vertical height ($P > 0.05$), there was no significant difference between the two jumps in the elevation height of sacral Y-axis ($P > 0.05$), and there was no significant difference between the two jumps in the speed of feet off the ground at any time ($P > 0.05$). There was significant difference in trunk angle between the two jumps at the lowest point of mass center ($P < 0.05$). There was significant difference in the angle of left and right knee joints at the time of CMJ jump standing ($P < 0.05$). There was significant difference in knee joint angle at the time of toe off ($P < 0.05$), and there was significant difference in ankle joint angle at the time of toe off ($P < 0.05$). In vertical jump, the reaction time law of squat jump and semi squat jump is the same, and the recovery standing time is the longest, followed by the take-off time and reaction time. The two vertical jump methods have no effect on the height, time, and speed of exercise take-off. The different take-off modes lead to the asymmetry of left and right knee joints when leaving the ground and the asymmetry of left and right ankle joints when landing. There is the phenomenon of left and right force imbalance. The two vertical jumps show the same difference trend, reflecting that the two jumps cannot be distinguished through simple kinematic parameters, and need to be further distinguished in application.

In the test of exercise performance, this study did not find that the two squatting movements will lead to the difference of exercise performance. The reason is that the original exercise habits of the subjects are not considered. One subject completes the action forms that he is not used to. Due to the uncoordinated neuromuscular control, the data will often be affected. Therefore, this problem should be considered in the selection of subjects in the future research. In addition, this study only compared and analyzed the kinematic and dynamic characteristics of lower limbs in different movements, and inferred the possible impact on the muscles around the joints, but did not actually measure the muscle activation and force state.

Therefore, it is suggested to add EMG test in future experiments to test and prove the reasoning of this study. At the same time, it can evaluate and analyze the sequence and degree of muscle activation in the process of movement, so as to further understand the influence of different squatting movements on the muscle contraction characteristics of lower limb joints.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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