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Analysis and research on the motion structure of the fatigue jump motion based on the sports biology.

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Abstract

Sports fatigue is an inevitable phenomenon, which plays an important role in the teaching and training of physical education. The explanation and application of some phenomena after sports fatigue have been the research focus of the relevant institutions at home and abroad. Based on this, the three-dimensional force, image analysis and other methods of motion biomechanics were used to test the continuous and unlimited 30 deep jump motion for 20 test subjects. By controlling the experimental conditions before and after sports fatigue, the research and analysis were carried out in the weightlessness, buffering, stretching and flight of the four stages, the characteristics of time, force and impulse before and after fatigue were studied from the comparison of the force and time curves, it was concluded that the changes of biomechanical parameters not only significantly reduced the effect of jump training, but also increased the risk of joint and muscle damage. The study shows that the research on the fatigue jump movement based on sports biology can lay the foundation for the correct physical training, and provide a scientific basis for mining the potential of sports.

Keywords: Motion structure, Fatigue jump motion, Sports biology.

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Introduction

Competitive sports play an increasingly important role in people's life, the result of competitive sports is a symbol of the national prosperity and the level of science and technology development. Fatigue is inevitable in sports and training, with the continuation of the movement time, it inevitably will consume the energy matter, produce the metabolite, and the muscle will change. In general, in the state of exercise fatigue, because the energy storage and dispersion capacities of muscle decrease, the output power reduces, the muscle can't carry the original load running, which will inevitably lead to technical movement deformation and the increase of muscle strain, stress fractures, destruction of joints and cartilage degeneration. Obviously, sports fatigue not only has a direct impact on the athletic ability of the athletes, but also is an important reason for sports injury. In the course of physical exercise, sports fatigue is inevitable, so the physical education and training are needed. At home and abroad, many scholars have carried out research on sports physiology and sports medicine, which can further reveal the relationship between fatigue and human movement, and ultimately provide a new way of thinking for the relevant sports training.

The Plyometric practice with a typical representative of the deep jump, its essence is a kind of method which uses the mechanical impact stimulation to force the muscle to extend the muscle strength as far as possible [1]. The effect of this short-term activity can be targeted to improve the reflex action of the feedback component, so that the muscles stretch not only can withstand greater loads, but also can store more elastic energy, so as to effectively promote the development of the running speed and explosive force, and improve the reaction ability of the nervous system [2]. Mccall et al. and others pointed out that the fatigue performs in subjective and objective physiological changes and biomechanical changes, including more significant changes in biomechanical properties [3]. Knicker et al. proposed that the definition of fatigue was: the physiological processes of the human body couldn't be maintained at a predetermined exercise intensity at a certain level [4]. In recent years, the concept of sports fatigue formulations has been more clear, because the physical fatigue caused by work or activity itself has been distinguished from disease, environment, nutrition, and other reasons [5]. Decorte et al. called it the whole body movement. Because exercise capacity and physical functioning may be show a recession, so it is needed to study sports fatigue, which is conducive to better training guide, so as to better improve the athletic ability and sports performance [6].

Athletes jump down from the static state, there will appear the gravity and inertia pulled of the foot, if the jumping action is completed, the body will appear empty phenomenon, this is also called the long power training method [7]. XX human body movement requires extreme speed, the terminal speed is obtained by the start in the opposite direction, the reverse brake creates the condition for the acceleration motion [8]. Deep

jump can achieve the stretch and contraction of the muscles, through the net, the object elongation can be achieved, and the body will be affected by gravity [9]. Then the human body does the upward movement, which is the upward movement accelerating to the heart, then the muscles quickly shorten, thus the reaction of the contractile form is a highly active form of contraction cycle [10]. Schlader et al. measured the vertical jump abilities through a variety of height, and then the rebound was converted to 23% of load positive power supply [11]. Buchheit concluded that the elastic muscle structure and contractile performance could withstand a strong passive stretch, and the characteristics of the structure and active muscle could promote the recovery of mechanical work [12].

At present, the research of deep jump is focused on the jump height, the depth of the load and the strength and so on, but whether there is damage and other issues in the training effect of sports fatigue are not clear. Therefore, a deep research on sports biomechanics was made in this paper, under the condition of this experiment, the structure of the jumping motion before and after the sports fatigue and the parameters of the sports shoes were compared and analyzed, so that the impact of fatigue on the body movements of the body was explored, so as to provide more scientific information for the various fatigue of the body, and provide a scientific basis for improving the body's ability to exercise, and then tap the potential of sports; Besides, this study can also provide the relevant training principles and training methods, and provide a theoretical basis for the new design ideas. Therefore, it is very important to study the change of the action structure and the effect on the lower limb joint muscle after the fatigue.

Experiments and Methods

Experimental design

In order to avoid the influence of height, weight, and muscle natural condition on the results of the experiment, according to the guiding ideology that the natural condition of the subjects is basically the same, the weight of the height and the weight factor are more easy to be controlled, as well as muscle can't be directly used to define quantitative indicators because of its properties, and there are no weight and clear correspondence. Therefore, in the design of the experiment, the idea of the "cross cancellation" is used, that is to say, there are two different human motions for the experimental subjects, through the overlapping, this crossed action can be considered to be the characteristics integration process of the muscles, which has a certain representation and universal significance. During the experiment, the data collection of a total of 20 people (male) of the compulsory exercise was completed. The natural situation of the experiment object is shown in Table 1. The good effect data of 10 persons is the effective data.

Table 1. *The natural condition of the experiment object.*

Number	Age	Height (cm)	Weight(kg)	Sports experience
1	22	176	65	commonly
2	21	181	74	More time
3	21	176	74	More time
4	20	181	80	commonly
5	23	177	73	More time
6	25	183	78	commonly
7	21	175	76	commonly
8	22	172	69	More time
9	22	180	77	commonly
10	24	173	68	More time

In the experiment, through the movement way of the human body, the comparative analysis of sports fatigue can be carried out, and after exploring the effects of fatigue, the basic structure of motion can be produced. For sports fatigue, patients will carry out a vertical jump of 30 consecutive times, and through three dimensional force measurements and the experiment object tracking, the lower limb of subjects can be judged if it is tired. The purpose of this study is to explore the effect of sports fatigue on the motion structure. Because the result of this kind of action is still unknown, so taking into account the objective of psychological and physiological factors, exercise physiology and experimental design basis, the applied load is designed to jump up to 50 cm deep load.

Experimental methods

The time curve of ground reaction force was recorded by using the biomechanical force measuring platform. Charge amplifier was preheated for half an hour, the sampling parameters were set for "automatic trigger", then the camera was used to carry out a two-dimensional video shooting and shoot the whole process of motion. By means of 3D image motion analysis system, the real time capture measurement of human motion was carried out, so that the 3D trajectory data of joint points of the human body was obtained. Based on the 3D trajectory data, the displacement, velocity, acceleration and other motion information of the joint point of the human body could be easily obtained. Besides, it was necessary to wear high elastic tight pants to avoid unnecessary damage to the test, and the experimental objects needed to prepare activities, so as to fully active skeleton, knees, feet and other joints as well as leg muscles. All the test actions were required to put hands on hips and upper body upright. Then the 30 times of infinite longitudinal jumps were carried out, at the same time, the camera was used to track the high altitude, and vertical force of the three dimensional force test was carried out. At the end of the vertical jump, the subjects were asked to immediately jump to 50 cm.

The video clips could be carried out by the true to life software, the digital processing of moving images could be realized, and the smooth processing of the data also can be carried out. The 17 joint points in the human body were obtained by the Zyl J Ki model, then the data analysis and calculation could be carried out, so that the original data was

obtained, and after digital filtering and other smoothing methods, which could be completed in the international software package, finally, all kinds of data needed in this paper was obtained.

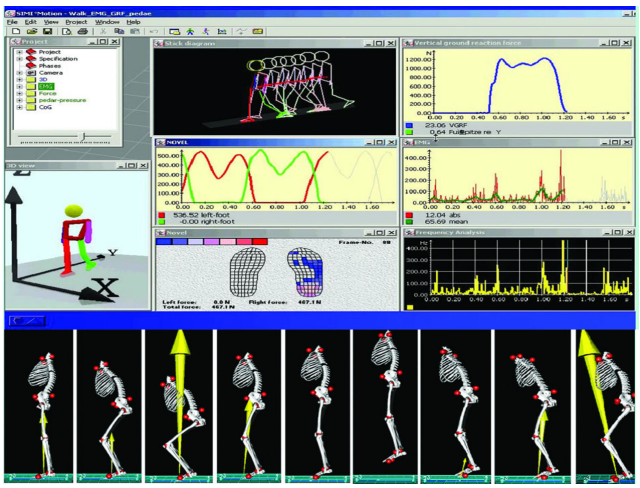

Figure 1. *Three dimensional image motion analysis system.*

Action Division and Index Selection

Action stage division

The ways of the classification of the vertical jump are not unique; the classification criteria are not uniform. The classification of the standard parameters should have the objectivity and applicability, which not only reflects the characteristics of the operating target, the analog should also be simple. Correct phase classification is the vertical jump action research, based on the calculation of all quantitative indicators, the jump deep action is divided into four stages at home and abroad, namely, buffer stage, weightlessness stage stretching phase and the flight phase [13].

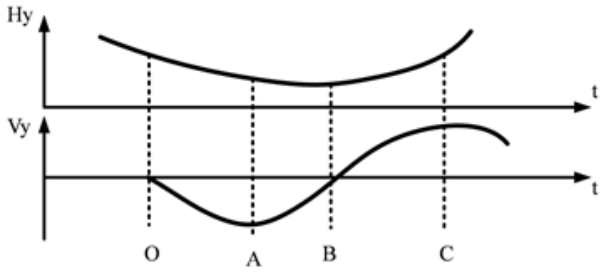

Figure 2. *Vertical jump center of gravity, speed change curve and phase division.*

As shown in Figure 2, point O is the point that the foot contacts with the ground, it is called the start point; the speed of point A is the minimum, that is the maximum downward velocity, it is known as the buffer point; point B is the lowest point of the body's center, the speed of this point is zero, which is the focus of the movement direction of the turning point, the body completes the maximum buffer on this point, so which is known as the pedal extension point. Point C is the point with the maximum speed, which is another turning point of the size of the speed, the ground reaction force is equal to the weight at this point, and the turning point of the direction of the acceleration is known as the off site. In this paper, Weight loss phase (OA), Buffer stage (A-B), and Extension stage (B-C) were researched.

Weight loss phase (OA): Weight loss phase is also known as the preparation stage. The body presents the state of curved skeleton, knees and feet do the squat, the calf is in a state of relaxation, so as to make a concession centrifugal contraction. At this time, the center of the body is down, the ground reaction force is less than gravity, the acceleration and the center of gravity have the same displacement velocity, in the process of weight loss, the ground reaction force at the point A is equal to the weight, the acceleration is zero, and the weight loss is over, the speed of gravity downward moves to the maximum.

Buffer stage (A-B): Buffer stage is also known as the centrifugal contraction stage. Buffer stage refers that the velocity of the body's center of gravity moves downward to the maximum of the knee; the method of the determination of maximum buffer phase of the center of gravity is to regard the biggest buffer time as the lowest of the axis of the knee. If a point does downward movement of gravity, the lower limb muscles will move down, but it will still have the muscle tension, finally lead to eccentric contraction. At the point of B, the body's gravity is zero, and the body's gravity moves down, at the end of the centrifugal extensor contraction tension, tension will reach the maximum value, so that the maximum buffer is completed.

Extension stage (B-C): Extension stage is also known as the radial contraction phase. Extension stage is the moment from the maximum buffer to the moment of the human foot away from ground for the human knee joint; The determination method of the moment that the foot away from the ground is based on the method of dynamics and the corresponding picture. When the center of gravity of the body of point B changes the direction of movement, the muscle contraction appears, that is, the heart muscle contraction, until the reaction force of which is equal to the gravity, the direction of acceleration will change, so as to achieve the maximum speed and complete tic stretch of the action.

The determination of the flight phase is the moment from the maximum buffer to the moment of the human foot away from ground for the human knee joint. The structure relation of the muscle contraction, reaction force, center of gravity displacement, velocity and other kinematic and dynamic factors in the vertical jump process has the following characteristics (Table 2).

Human body model

As shown in Figure 4, in the study of vertical jump, the human body consists of four parts (in addition to the head and arm), namely, thigh, leg, foot and so on, and that is, which consists of four parts of the rigid body. From the body to the ground is a

chain during physical exercise. Some aspects of the chain movement can lead to the movement of the other links. Joint angle is defined as the body upright, when the body torso, thigh and leg are in a straight line, which is a180 degree angle of the knee, this is enough to complete the dance music, when the foot and leg are in a straight line, it is 180 degrees.

There are three regular shapes of rigid body of the human body, the link is the connection between the hinge. Ankle angle is carried out the general provisions of the calculation: The ankle angle is the angle between the legs, the long axis is defined as the connection from the heel to the toe, and the two lines of the joint don't intersect. Therefore, the method of calculating the ankle angle correction is used to select the angle between the long axis of the leg to the ankle.

Table 2. *Description of the basic characteristics of each phase.*

	Phase	Action structure	Contraction mode	Acceleration	speed
Weightlessness stage	O-A	Hip, knee and ankle squat	Passive stretching	≤ 0	<0 to the maximum negative value
Buffer stage	A-B	Hip, knee and ankle squat	Centrifugal contraction	>0	<0 to =0
Kicking and stretching stage	B-C	Hips, knees up	Concentric contraction	≥ 0	>0 To the maximum positive value
The flight phase	After C	Air position			

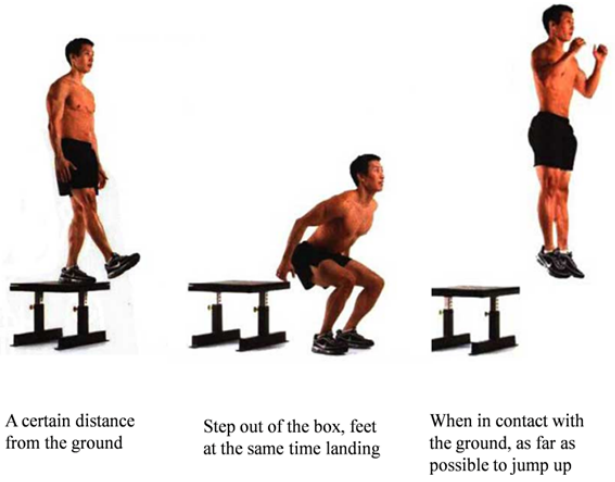

Figure 3. *Jumping motion diagram.*

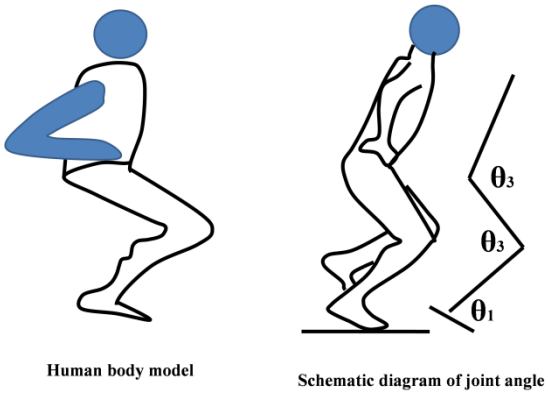

Figure 4. *The human body model.*

Index selection

In a large number of researches of vertical jumps, the characteristic exponent is studied. From the point of view of the research, the purpose of the main selection from the kinematics reflects the changes in the effect of muscle action. Among them, the exercise time is used to describe the cycle length of the operation; force value is used to describe the mapping of muscle tone; The research shows that: (the standard weight) the minimum force and the buffer force can reflect the average buffer quality, within a certain range, the smaller the value, the better the quality of the buffer; Centrifugal force gradient segment buffer can reflect the conversion, the bigger of the value, the better the situation; Buffering capacity can reflect the average buffer quality, in a certain range of values, the smaller the value, the better the quality of the buffer.

Results and Analysis

Comparison between force and time curve

Non-quantitative comparison of force versus time curve is observed, and the simple fact that there are differences is found, this method is a good way to find the starting point of research [14]. The force and time curves reflect the vertical ground reaction force after the whole process, which is the external expression of the internal force of the human body. From the Figure 5, it can be seen that the curves of force and time show unstable fluctuation characteristics in the deep jump, the following figure is force and time curve of the same subject before and after the fatigue, in which, in the case of non-fatigue, the stress values show the stability of doublet, and which shows an unstable multi-peak change after fatigue.

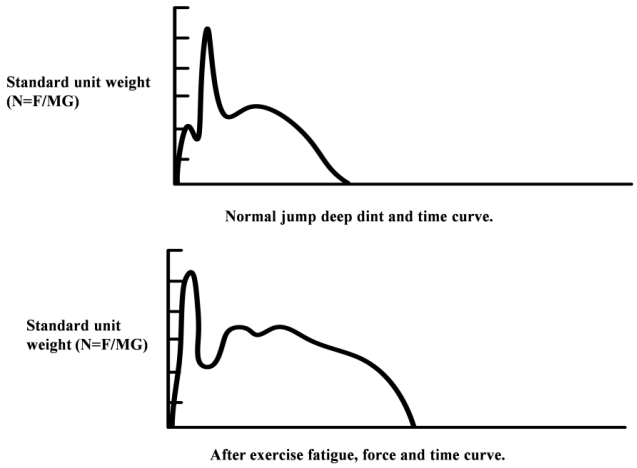

Figure 5. *Before, during and after the fatigue strength and time curve.*

Combined with the image drop jump recorded by camera, due to the increase of the instantaneous impulse, the first peak force of the time curve of the jump depth is formed; Due to the buffering effect of the body's small joints, the force value rapidly declines, so as to form the first valley. The heel forms the brake, so that the ground reaction force rapidly increases then the force and time curve form second peaks. When the human body motion transient lower limb is weak, the original motive muscle is not stable, at the same time, the strength of the muscle is constantly adjusted, the speed and the acceleration are not stable that is the reaction force is not stable. At the same time, the direction of the change of body fatigue also affects the vertical force fluctuations. Based on the observation curve and image analysis data, it can be found that the fluctuation of this kind of force is mainly reflected in the later stage of the buffer stage, and the process of the stage of the two stages. It can also be seen that the effect of exercise fatigue on the force value is mainly concentrated in the late stage of the buffer stage and the stage of the whole therefore, the differences of other indexes should be mainly concentrated in the area after the comparison of sports fatigue.

Time characteristics of each stage before and after exercise fatigue

The study on the dynamic characteristics and the kinematic characteristics of the jump takes the center of gravity as the basis. The deep jump is divided into weightlessness stage, buffer stage, push off phase and the flight phase. The time characteristics of each stage of motion fatigue are shown in Figure 5. It can be seen from the Table 3, in the total time, the time after the fatigue is also significantly less than the time before the fatigue. In the stage of weightlessness, the time variation of motion fatigue is about 0.012 seconds; In the buffer stage, the amount of time before and after exercise is about 0.014 seconds, the difference of weight loss stage and buffer stage is significant ($P<0.05$); And the time in the extension phase slightly extends, the T test is carried out, and the value is 0.896 ($P>0.05$), so the difference is not significant. The weight loss period and the cushioning period have a curved bone, and a knee and foot squat. Muscle contraction is a passive way of stretching and centrifugal contraction. The leg muscles are in a state of relaxation, the body is in a state of weightlessness, the lower limb extensor muscles continue to resist the downward movement of the eccentric body. The time of weightlessness and buffering will become shorter and may even lead to insufficient elastic energy reserves, which affects the jump. For the duration of the extension which is consistent with the relevant researchers in the study of vertical jump. When the human body is tired, the coordination relation between the muscle contraction speed and the movement center which governs each muscle group will be effected. As a result of muscle fatigue, the explosive force is reduced, in order to make the jump deep action coordination, smooth, the time the extension is extended.

Table 3. *Time value of each stage before and after exercise fatigue.*

No.	Under normal circumstances				Under the condition of fatigue			
	weightlessness	buffer	Stretch	Flight	weightlessness	buffer	Stretch	Flight
1	0.16	0.2	0.24	0.3	0.18	0.158	0.242	0.28
2	0.16	0.13	0.29	0.2	0.16	0.151	0.251	0.2
3	0.16	0.122	0.198	0.2	0.14	0.15	0.23	0.16
4	0.14	0.144	0.256	0.24	0.12	0.112	0.228	0.3
5	0.1	0.15	0.35	0.18	0.16	0.176	0.285	0.29
6	0.2	0.16	0.26	0.26	0.18	0.146	0.314	0.32
7	0.14	0.16	0.26	0.26	0.14	0.156	0.244	0.321
0	0.22	0.186	0.274	0.3	0.1	0.084	0.297	0.3
9	0.12	0.12	0.16	0.18	0.12	0.12	0.28	0.18
10	0.2	0.242	0.368	0.27	0.18	0.218	0.292	0.25

S	1.6	1.614	2.636	2.39	1.48	1.468	2.662	2.94
X ± SD	0.160 ± 0.038	0.161 ± 0.038	0.264 ± 0.063	0.239 ± 0.046	0.148 ± 0.029	0.147 ± 0.036	0.266 ± 0.031	0.294 ± 0.056

Change characteristics of the force value before and after sports fatigue

In the experiment, the three dimensional force platform was used to get the curve of the force of the ground reaction force in the vertical direction, horizontal direction and the front and back direction. Based on the classic theory, it can be found that when you fall on the ground with the same height, the object will gain a greater ground reaction force. Here the analysis is carried out from the vertical force change: in order to obtain a certain speed, the human body movement must rely on angle of the external force to the human body. Deep jump is to rely on the body's own weight, through the coordination of the various components, based on the role of the lower limb joints and the lower limb muscles, the reaction of people obtained is changed to the human body movement.

Table 4. *Peak force of vertical direction before and after exercise fatigue (N).*

Number	The peak force of vertical direction under normal condition	Peak force in the vertical direction under fatigue condition	
1	33.76321	32.95231	
2	37.9221	31.6732	
3	64.42108	61.45012	
4	44.83389	40.78921	
5	64.75231	30.83721	
6	33.73452	31.54903	
7	58.36789	51.64232	
8	71.86238	59.35234	
9	63.14223	52.14632	
10	28.70233	27.67342	
X±SD	50.15±15.98	42.008±12.931	=0.029<0.05

From the Table 4, it can be seen that the vertical force value of the deep jump before and after fatigue reduced from 50.15 ± 15.98 to 44.01 ± 13.57. The T test of the value was carried out, it can be found that there was a great difference ($P<0.05$). The maximum force value reflected the acceleration of the vertical force upward movement of the ground acceleration peak value after the human body's jump. It was related to the size and weight, and was mainly dependent on the coordination and activity of the lower limb muscles, so as to speed up the efficiency of all aspects. When the body reached fatigue, muscle function and efficiency were consumed by ATP and CP, the decline in the efficiency of muscle activity led to a decrease in muscle contraction, so that the vertical component decreased. For the vertical component, the muscle output power was directly proportional to the degree of decline. Therefore, the vertical force of the jump can objectively reflect the motion of the lower limbs muscle fatigue state.

Change characteristics of impulse before and after exercise

The magnitude of the impulse value was determined by the time between the two variables, that is, the area of the closed area, therefore, the change was complex [15]. There was the component of the jump, which led to the presence of the impulse value, in which, Ix, Iy were the sum of absolute value of impulse in the front and back direction and the left and right direction in the course of the jump, Iz was determined as the difference between the positive impulse and the negative impulse of the weight line in the course of the jump.

Table 5. *Changes of the impulse value before and after exercise fatigue (N·S).*

	Sports fatigue	After sports fatigue	P
IX(N·S)	52.73 ± 17.17	71.70 ± 28.95	=0.020<0.05
IY(N·S)	30.51 ± 10.50	40.43 ± 6.68	=0.017<0.05
IZ(N·S)	519.66 ± 70.26	488.04 ± 53.37	=0.025<0.05

As can be seen from Table 5, the impulse value in the front and back direction and the left and right direction increased, and for this increase, the direction of the front and the back was significant, the direction of the left and right was also significant. In the vertical direction, the red amplitude was small, and had significant difference. With the occurrence of lower limb fatigue, the component values of all directions changed, and the time also changed, then the impulse value changed too. After the exercise fatigue, the central nervous system will reduce the muscle control, which is not conducive to the increase of the pulse before and after. So before and after the jump, the left and right direction change can objectively reflect the muscle control ability and the excitement of the central nervous system and the strength of the nerve muscle control. Therefore, the descent of the impulse value in the front and rear of the jumping depth can reflect the fatigue state of the muscles during the movement. As the magnitude of the vertical thrust change, this is mainly due to the depletion of muscle ATP, CP, so as to make the output power of the muscle decreased.

Conclusion

Exercise fatigue has a greater impact not only on skeletal muscle activity, but also on the technical action structure of the human body in the movement. The test of continuous and

unlimited 30 times of deep jump motions for 20 test subjects was carried out in this paper. By controlling the experimental conditions before and after sports fatigue, the four stages of the weightlessness, buffering, stretching and flight were studied, and the characteristics were analyzed, then the point that the sports fatigue will have a great negative impact on the action of the jump was obtained. Results show that the time variation of each stage is obvious, so that the action structure and effect are affected. Therefore, the coaches need to carry out different training according to the physical condition of different athletes, and carry out appropriate adjustments to the load and the strength, so as to avoid sports injuries. In the whole process, the change of the angle of the joint will appear, and the centrifugal contraction will be caused, and the elastic energy reserves will also reduce. In addition, muscle shortening amplitude decreases again, which greatly reduces the muscle and external work and ultimately reduces the effect of vertical jump. The force values in the vertical direction decreases after fatigue, and in the front and back, the change in longitudinal direction is opposite, so that the efficiency of the operation reduces, and the jump height is decreased. In daily physical education and training, the observation and tracking of these indicators can be more intuitive to judge fatigue, and can be judged earlier, as it is very meaningful to avoid excessive fatigue. Practice proves that the analysis of the change trend of biomechanical parameters after exercise fatigue can define the scope of sports injury, and then avoid the occurrence of sports injury in the sports training and teaching.

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