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The design of sports system for improving the explosive force of the lower limbs.

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Abstract

With human society entering the twenty-first Century, people have paid more and more attention to sports. And in recent Olympic Games, China athletes have got good results for the glory of the Chinese nation, and also promoted the development of sports in China. In all kinds of sports, the explosive force of the lower limb has a great impact on the competitive sports. In order to get better athletic performance, we need to adopt more scientific and reasonable training methods to improve the explosive force of the athletes' lower limbs. With the development of science and technology, the application of computer technology in sports has been more extensive. Through the computer system, the acquisition, storage, analysis of related images, strength and other data of the athletes in the process of sports were carried on, to find out the lack of action, and the targeted training methods were put forward. In the design of the sports system which improves the explosive force of the lower limb, the design of motion picture system and the system design of three dimensional force measuring platform were completed. In this way, the collection and analysis of the motion image and the dynamic correlation data were carried out. Finally, through the test of the system, it can be seen that the system can fully analyze the data parameters of the athletes in the training action, and provide data base for the training to improve the explosive force of the lower limbs of athletes.

Keywords: Improvement, Lower limb, Explosive force, Motion system.

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Introduction

With the development of human society and the changing of life style, people pay more and more attention to the health of people, and all kinds of forms of sports competitions are in full swing. World class events such as the Olympic Games, the world cup and so on can bring glory to athletes, and also actively promote the development of the world wide range of sports [1]. In most sports, jogging, swimming, gymnastics and weightlifting bring people great enjoyment and perception, and the movement of its sports also needs a strong body power, especially the explosive force of the lower limb [2]. To complete the speed or force promotion in a relatively short period of time, it is required that the athletes through training to obtain the amazing explosive force. And there are many training methods, such as extra-long training, resistance training, and strength-endurance training. In the face of so many training methods, how to choose a scientific and reasonable system training method is the problem that many athletes have to solve in order to improve their competitive level.

With the development of computer technology, people can obtain the action of the athletes' movement and the biological force data through the video image and the sensing element, and the application of sports digital system is more and more extensive [3]. However, the traditional sports system usually only makes a simple analysis of the kinematic data with no combination of biomechanical research, and it is difficult to meet the lower limb training research of improving the explosive strength. In this regard, by combining the image system and three-dimensional force measurement system, the image data of the movement and force of the athletes in the movement process were collected, analyzed and applied, and the specific training methods can be selected according to the specific physiological characteristics of different athletes [4]. After the system design is completed, it can be seen that the function of the system is running normally through the test of the athletes. It can be used in the training of improving the explosive force of the body, which has a certain reference value for the design of similar systems.

Research on the Explosive Force of Lower Limbs and the Digital System of Sports

The explosive force of the lower limb

In 2016 Rio Olympic Games, the Chinese delegation won 26 gold medals, of which there are 5 weightlifting items.

Competitive sports have increasingly become the focus of people's attention, and the sports items similar to the weight lifting have high requirements of the lower limb's explosive force [5]. Therefore, research to improve the strength of the lower limb is not only helpful to improve the level of competitive sports, but also to improve the sports performance in our country from a scientific point of view. No matter what kind of economic activity, it must have a certain quality of strength. The quality of explosive force would directly affect the effect of motor skills, and it is needed to train the strength quality of athletes [6]. At present, the classification of muscle strength includes rapid strength, strength endurance, and the maximum strength and so on. With the continuous development of sports research, the rapid force generated by muscle contraction form has become an important research content. Muscle contraction force is increased by super isometric exercise, muscle eccentric contraction and so on, which can improve the explosive force of the muscle [7].

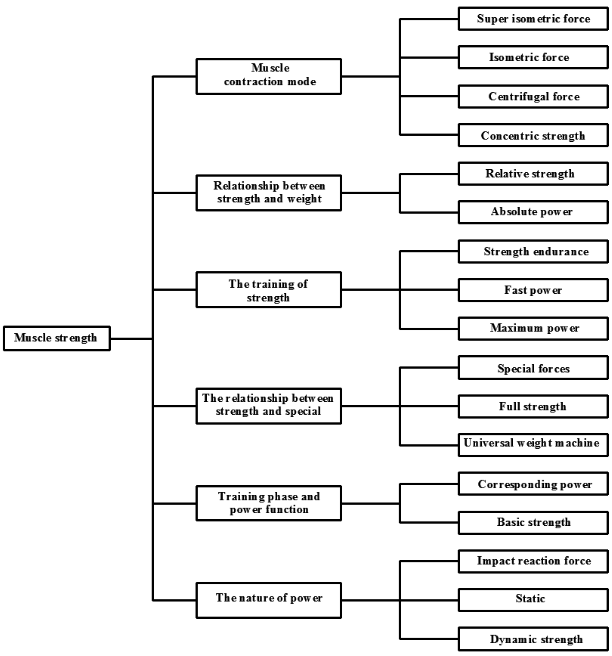

Figure 1. Classification of power quality.

In the lower limb explosive force training, fast strength exercises can increase the thickness of the capillary network, which can better satisfy the nutrients and oxygen to muscles during exercise, and improve muscle oxygen reserve ability [8]. There are many ways of fast strength training, with the commonly used hop and step jump. In the use of deep jumping exercise, the jumping movement can be completed by eccentric contraction and concentric contraction of lower limb muscles, and ultimately the explosive force of the lower limb could be improved. The existing research also showed that the use of different heights of jump could improve the performance of the athletes significantly, and it became the commonly used exercise mode to enhance the explosive force [9]. In the strength training, in addition to pay attention to the selection of training methods, it also needs to reasonably control the training load, making the organic combination and unity of the two, and the number of groups, weight, speed, and interval of the training should be configured. In the detection of rapid strength, the detection types of muscle strength often used include muscle strength, muscle strength, kinetic parameters, and kinematic parameters test [10]. For the athletes, not a single muscle is able to complete an action, but different muscles are needed to work together to complete it. Therefore, when the test is carried out, it is not able to take a single muscle as the standard of measurement. Taking the kinematics index test as an example, the test indexes contain the shuttle run, standing long jump, high jump and single leg jump, so as to comprehensively judge the training effect [11].

Figure 2. The application of the explosive force of the lower limbs in competitive sports.

Sports digital system technology

With the development of science and technology, the application of computer analysis software in sports is more and more reflected its special value. Through the computer system, data collection, storage and analysis of the related image and strength of some movement can be carried on. Carry out scientific and rational analysis, and find out the shortage. And special improvement and training are made according to the different characteristics of the athletes, in the continuous comparative analysis to improve the skills of the athletes and physical function [12]. On the whole, there are three kinds of the relevant software of sports system: Measurement and analysis software, image analysis software and technical analysis and statistical software. Through the software, the players can be taken pictures to obtain the image in the process of motion, so as to calculate the speed, height, position and so on. A variety of force and infrared light sensor acquisition signal can also be used, and finally the three-dimensional space system can be established through the 3D software analysis [13]. The application of computer digital technology in the analysis of sports can make the training more scientific and more technological, and promote the development of sports in China. The current digital training system is often using a three-dimensional or two-dimensional way to restore the related technical action of motion simulation project. A new action can be designed through the revision of the new action, in order to figure out the quantitative analysis of technical movements, so as to carry out targeted technical guidance for athletes [14]. In addition, the athletes' training action is compared with the standard simulation action or other outstanding athletes' action, and it can easily find the technical shortcomings and deficiencies of the athletes, and improve them. In the part of the sport, the sports system can also be used to make the whole program based on the characteristics of the movement of the athletes. In the Rio Olympic Games, the Chinese women's synchronized swimming program was organized in the computer software system. The whole program had a strong sense of Chinese flavor and law, very suitable for Chinese athletes, and it also made China in the collective project win the silver medal good results.

In the sports digital training system, the video segmentation technology is more common. Segmentation method is divided into segmentation methods based on threshold and region, and the use of image gray level change detection method is also more commonly used [15]. In the traditional video segmentation algorithm, the segmentation is using the space passage or change detection as the segmentation criterion. Firstly, enough frame difference information is accumulated to complete the reconstruction of the background image. The next is to extract the moving object, and then use the tracking technology to remove the larger noise, and finally the morphological operator is used to smooth the edge [16]. The specific algorithm flow chart is as shown in Figure 3.

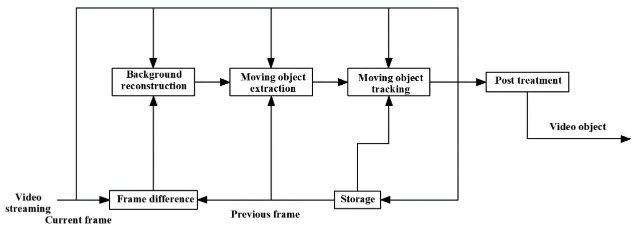

Figure 3*. Algorithm flow of video segmentation.*

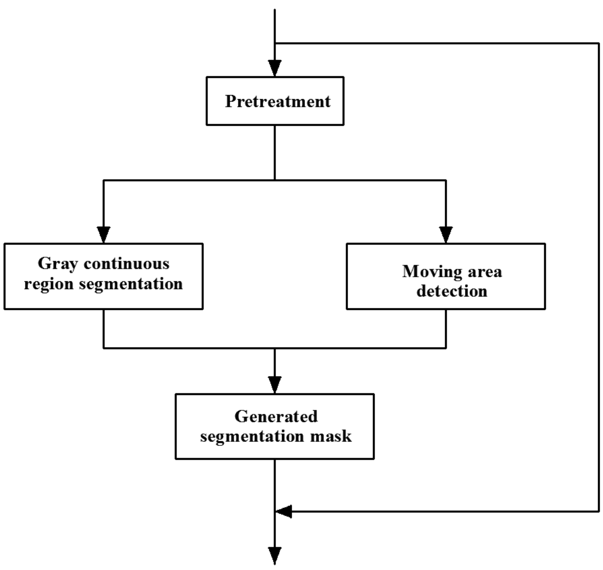

Figure 4*. Video object segmentation method based on gray continuous region segmentation.*

However, due to the segmentation algorithm still has many problems, such as the sensitivity of the noise problem, the segmentation method based on the continuous gray area is proposed, using pixel motion information between frames to obtain information of motion region and improve the accuracy of segmentation [17]. Assuming that a connected region in the image *I* is *R*, and *dk(i, j)* is the frame difference of the binarization. Where *(i, j)* is the specific pixel location, the gray value of the *k* frame pixel is set to *greyk(i, j)*, the threshold of binarization is T, then there are:

$$dk(i,j) = \begin{cases} 1 & |greyk(i,j) - greyk - L(i,j)| > T \\ 0 & |greyk(i,j) - greyk - L(i,j)| \le T \end{cases} \rightarrow (1)$$

It can be further improved using the second frame difference method, and we can get:

$$dk(i,j) = \begin{cases} 1 & d(i,j) = d(i,j) = 1 \\ 0 & others \end{cases} \rightarrow (2)$$

Each element in the matrix is represented by 1 or 0 in the background area or in the area of motion. From the static background, the foreground region is segmented, and the human interaction process is omitted, which greatly simplifies the whole segmentation process, and can effectively suppress the influence of noise, and the accuracy is relatively high. In the specific action of sports, the foreground and background of some action should be overlapped. This not only needs the effectively remove of the background of the frame to be superimposed, but the value of the superimposed area also needs to be considered. The frame which needs to be added is used as an anti-radiation transform, and the frame is projected into a panoramic image coordinate system. A gray image can be obtained by the difference between the projected frame and the background image:

$$\varepsilon(x,y) = |R_F(x,y) - R_B(x,y)| + |G_F(x,y) - G_B(x,y)| + |B_F(x,y) - B_B(x,y)|$$

$$D(x,y) = \begin{cases} 0 & \varepsilon(x,y) < \varepsilon_0 \\ \varepsilon(x,y) & \varepsilon_0 \le \varepsilon(x,y) \le 255 \\ 255 & \varepsilon(x,y) > 255 \end{cases} \rightarrow (3)$$

In formula (3), the coordinates of the panoramic map are x,y, D(x,y) represents the difference map drawing, and ε_0 is the empirical threshold value. Because there is much noise in the difference image, the median method is needed to smooth the filter, thus the difference between the foregrounds tends to be smooth.

Target tracking algorithm has a direct impact on the accuracy of the tracking results, and in sports, the change of the movement speed is huge, so it is necessary to make a better prediction. And the accuracy of the target tracking algorithm is very much dependent on the choice of the target model, such as using the color histogram as the object model, the color distribution of the target can be extracted. Assuming that y is the center of the tracked object, the width of the rectangle window is h, and the color distribution of the target is:

$$q'(y) = \{q'(y)\}_{u=1,\cdots,m} \quad \sum_{u=1}^{m} q_u(y) = 1 \rightarrow (4)$$

In the formula (4), the function is:

$$\sigma(x) = \begin{cases} 1 & x = 0 \\ 0 & x \neq 1 \end{cases} \rightarrow (6)$$

The module structure diagram of the tracking algorithm is as shown in Figure 5.

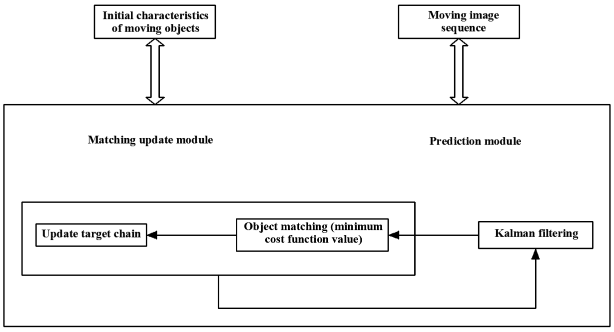

Figure 5. *Tracking algorithm module structure diagram.*

According to the difference between the environment and the object, the measuring method of muscle strength is divided into sports field and laboratory measurement method. Instrument for measuring muscle strength in general composed by the isokinetic dynamometer, measuring system, measuring platform and steering force measuring instrument. The measuring position and the purpose of the research are also different. Methods of measurement of the strength include back muscles, sit squat, grip strength, standing triple jump in three, solid ball etc. Muscle can play a strong force in a short period of time, and the explosive force itself is the role of the rapid force [18]. Taking the three dimensional force platforms as an example, according to the different sensing elements, it can be divided into a strain type force measuring platform and a piezoelectric force measuring platform. The strain type force measuring platform has a better detection effect on the static force and the quasi-static force, and the piezoelectric force measuring platform is better for the detection of dynamic and impact force.

Sports System Design for Improving the Explosive Force of the Lower Limbs

System design of motion image

System design includes motion image capture analysis and three-dimensional force platform, which can achieve the motion's video segmentation and action freezes, so as to achieve the analysis of the entire movement. At the same time, combined with the three-dimensional force platform, the force on the ground or instrument in the process of human body movement is analyzed, including the direction, size, time and other data of the force measurement [19]. The entire system is mainly to study the physical training to enhance the strength of the lower limb, through the existing system to improve and add some features. The entire software includes VideoPanel, suiButton, suiForm and other controls, and the main function of image processing system is shown in Figure 6.

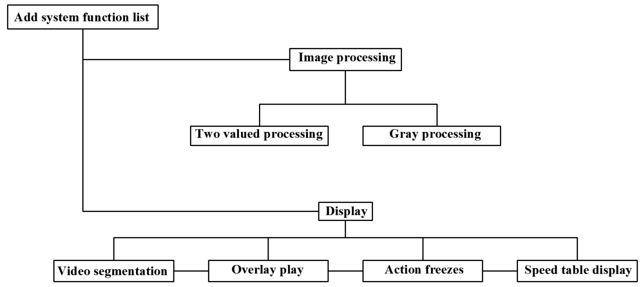

Figure 6. *List of image processing functions.*

In the video image processing, the used color space is RGB, that is using combination of the 3 basic colors of red, blue and green:

F= α.R+ß.G+γ.B → (7)

The image file format is BMP, including the bitmap file header, color palette and bitmap information header, and the number of bytes per line is multiple of 5. Image processing uses the continuous frame difference method for video segmentation. Set the threshold T, the pixel value extracted of each frame of the image is $I_i(x,y)$, and the difference between the two values is:

$$D_i(x,y) = \begin{cases} 255 & I_i(x,y) - I_{i+1}(x,y) \geq T \\ 0 & I_i(x,y) - I_{i+1}(x,y) < T \end{cases} \rightarrow (8)$$

Then compared with the pixels in the original image, the pixel value is returned:

$$I_i(x,y) = \begin{cases} 0 & if\left(D_i(x,y) = 0\right) \\ I_i(x,y) & else \end{cases} \rightarrow (9)$$

The image freeze algorithm is to overlay the adjacent images orderly, that is:

$$V_F(x,y) = \left(R_0(x,y), G_0(x,y), B_0(x,y)\right)^T \rightarrow (10)$$

Detection of moving objects is made by the method mentioned above. Compare the images before and after the smaller time interval, so as to distinguish the background and the moving object. In the choice of time interval, it needs to take into account the speed of motion, its framework is as shown in Figure 7.

The system design of three dimensional force measuring platform

The measuring force platform system is used to analyze the dynamic data, and the coordinates of the acting force and reaction force are established. Complete the low-pass filter through the filter, and import data in the Excel according to the needs. In the design of the motion system, it is needed to obtain the kinetic data that need to be obtained have peak ground reaction force, joint power and lower limb stiffness. In the measurement, the output data of different force, torque and pressure center is carried out according to the matrix equation.

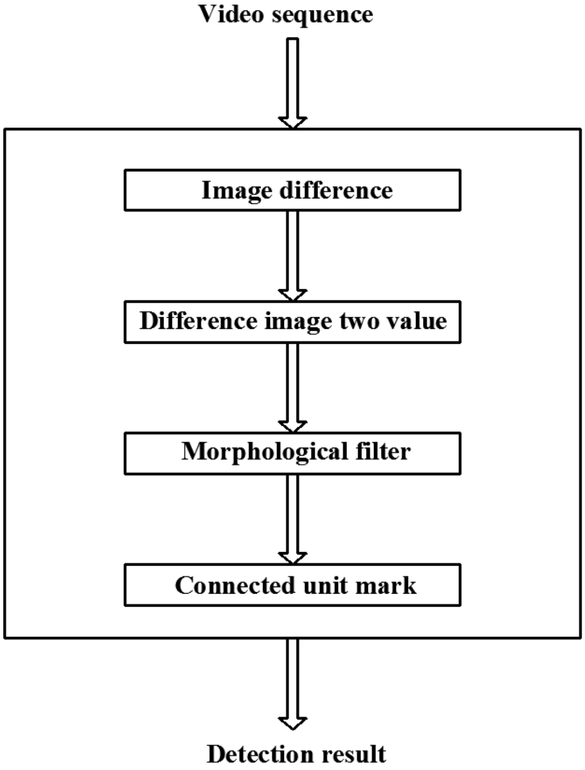

***Figure** 7. Frame difference method moving object detection framework.*

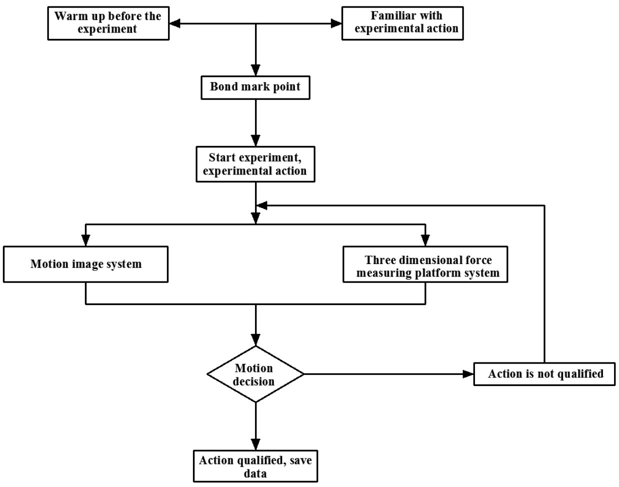

***Figure** 8. Frame difference method moving object detection framework.*

Firstly, the joint angle is defined as the axis angle of two joints of the link, which is a relative angle. At present, the method of determining the joint angle generally has the "three points" or "four points" method. Simplify the leg and thigh into a simple line. And in the calculation of the joint angle, the simple calculation of the angle between the two lines is done.

In the process of movement, joint works on lower limbs. The contribution of the joint objectively reflects the needs of the muscles in the process of lower limb movements. It is an important reference index for muscle training and improving the power of the outbreak. Integral joint power in time is the joint work, specifically:

$$W = \int_{t}^{l+T} P_j(t) \cdot dt \rightarrow (11)$$

In formula (11), $P_j(t)$ is the power of the lower limb joints. Assuming the net joint moment is $M_j(t)$, the angular velocity is $\omega_j(t)$, and the formula for calculating the joint power is:

$$P_j(t) = M_j(t) \cdot \omega_j(t) \rightarrow (12)$$

The formula for calculating the joint velocity is:

$$\omega_j(t) = \frac{d\theta(t)}{dt} \rightarrow (13)$$

The calculation of the stiffness of the lower limbs can fully reflect the reflex mechanism of the action nerve, including the vertical stiffness and the legs stiffness. A certain level of lower limb stiffness performance can make the muscle flex more effective to play out, so that it can effectively release the original stored in muscle, skeletal system of elastic potential energy in the process of moving the process. In the running, lower extremity stiffness and stride length is directly related to the running speed, and stiffness increase of lower limb joint will affect the increase of running speed. However, the effects of lower extremity stiffness on different running modes are also different. In the existing research, we can see that there is a very obvious linear relationship between the vertical stiffness and running, so for the measurement of the vertical stiffness, the relative relationship between the movement and force of the athletes can be directly observed.

It is assumed that the peak value of the ground reaction force is maxFleg, the position of the vertical direction is ΔL_{Ltrue}, and the vertical stiffness is calculated as: $K = \frac{\max F_{leg}}{\Delta L_{Ltrue}} \rightarrow (14)$

Application analysis

The system designed is used to carry out specific analysis of the kinematic and dynamic data, so as to obtain the specific parameters to improve the strength of the lower limb. Use squat jump as a concrete analysis of the object, and choose the right side of the body to conduct in-depth research. During the test, make full use of the system's ability to capture the image of the moving process and the monitoring function of dynamics, and analyze the relationship between the body movements and the biological forces in the process of squat jump.

Firstly, the kinematics data of hip, knee and ankle joint in different angles are analyzed, and the data at the angle of 90 degrees, 120 degrees and 150 degrees respectively are also analyzed. After the action is completed, the athlete carries on the weight to stand. The torso is forward at a certain angle, before the knee to the specified angle is the centrifugal stage, and part of the follow-up to the feet leave the ground is the concentric phase. Now the motion of different angles of the knee joint and the angular variation of the whole motion of the three joints are analyzed, and the specific results are as shown in Figures 9-12.

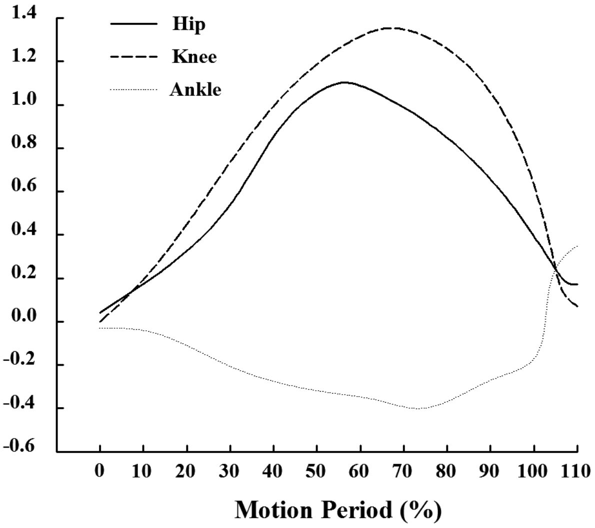

Figure 9. Angle and action of each joint (90).

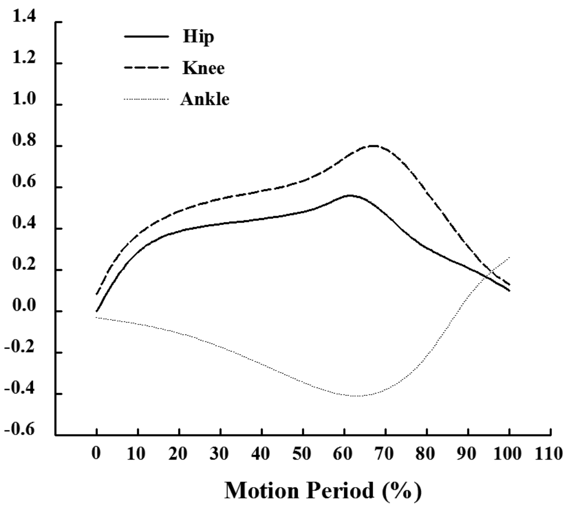

Figure 10. Angle and action of each joint (120°).

It can be seen from Figures 9-11, the hip, knee, ankle joint of the athlete's right leg and the percentage of the movement was tested, and through the change of the situation it can be analyzed: (1) When the knee angle is 90 degrees, the first to achieve the peak is the hip joint, and the last is the ankle; (2) When the knee angle is 120 degree, the peak value is the hip joint, and the peak value is the ankle joint; (3) when the knee angle is 150 degree, the peak value is the hip joint, and the peak value is the ankle joint. In general, for the three points in the test, regardless of the angle of the knee joint, the first peak is hip, followed by knee and ankle joints. It can also be seen that when the designed system is used in the study of kinematics, the image analysis and quantitative research of the athletes' movements can be made clear, which can make a comparative analysis of different actions, so as to obtain the same movement of the different laws of motion. The mechanical parameters of the athletes are selected to analyze the depth of the jump action, and the height of the jump is 60cm. And then the ground reaction force's filtering process of the two force stations of each action is completed. The mean and variance of the reaction force curves are obtained, and the curve of force and time was drawn (Figure 12).

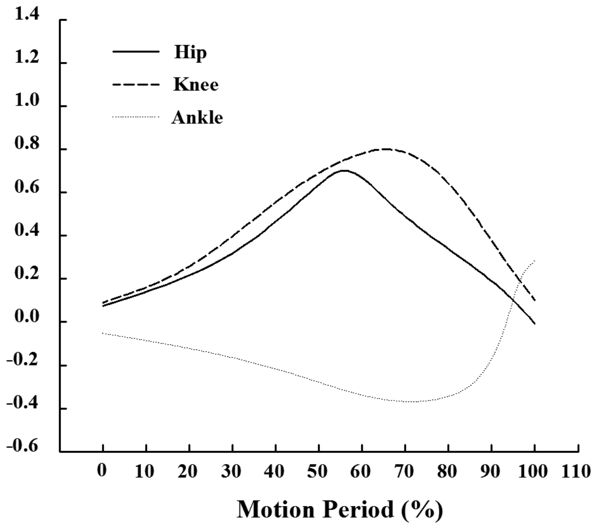

Figure 11. Angle and action of each joint (150°).

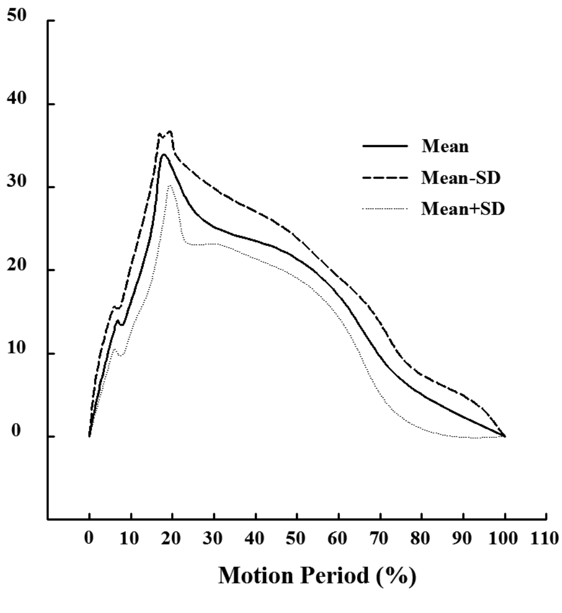

Figure 12. The ground reaction force and the percentage of action of the jump.

As can be seen from Figure 12, when deep jump height is 60 cm, the peak ground reaction force and movement percentage is 35.71 ± 6.5 N. The human body is simplified to construct a model, and the relationship between the ground reaction force and the movement of body flexion and extension is studied by the stiffness of the lower limbs. Specifically, when the human body makes jump deep action, it is the ratio between the maximum ground reaction force and the vertical direction of the maximum displacement. From the analysis results of the data obtained by the system, it can be seen that when the athletes vaulting height is 60 cm, the vertical displacement of sacrum is 0.18 ± 0.03 m, and the vertical stiffness is 182.54 ± 77.52 Nm/kg. Therefore, the system can study and analyze the dynamic parameters of the squat in detail, so as to obtain the body displacement, biological force data, finally presents the different effect of different movements on lower limb joints. Combining with the above study on the change of joint angle, the system can carry out the lower limb's explosive force training. More appropriate training methods for different athletes can be analyzed through the system and applied to training practice, in order to scientifically improve the explosive force of the athletes, and improve the level of sports competition.

Conclusions

Explosive force of lower limb plays a very important role in most sports programs, and even plays a decisive role in the part of the project. There are many training methods to improve the explosive force of the lower limbs. The research on the effect of different training methods on the body movement of the athletes has become an urgent problem to be solved in the training process of modern athletes. Using computing technology to make the acquisition and analysis of dynamic and kinematic data in athletes' training process, obtain the corresponding motion parameters, and carry out targeted training depending on the athlete's own physiological characteristics. In the sports system design, the design of the motion picture system and the system design of the three dimensional force measuring platform are carried out respectively. Among them, the motion picture system can realize the video segmentation, motion freeze and so on. The relationship between the body and the force's direction, the size, the action point and the time of the action surface can be obtained by the three-dimensional force platform. In order to test the application of the system, the body movement or the biological force test in the process of the movement of the athletes in the squat jump is carried on. The first is the completion of the kinematic data of the knee joint at 90°, 120°, and 150°. And the analysis of mechanical parameters of the 60cm height jump is completed. The test results show that the system can make the comprehensive analysis of dynamics and kinematics data in the training process of athletes, so as to provide reference for quantitative data for the athletes to improve sports training and lower limb's explosive force, and help to improve the athletic performance.

References

1. Aagaard P. The Use of Eccentric Strength Training to Enhance Maximal Muscle Strength, Explosive Force (RDF) and Muscular Power - Consequences for Athletic Performance. Open Sports Sci J 2010; 3: 52-55.
2. Hannah R, Folland JP. Muscle-tendon unit stiffness does not independently affect voluntary explosive force production or muscle intrinsic contractile properties. Appl Physiol Nutrition Metabol 2014; 40: 1-9.
3. Rastogi AK, Chatterji BN, Ray AK. Design of a Real-Time Tracking System for Fast-moving Objects. Iete J Res 2015; 43: 359-369.
4. Pastuszak G, Trochimiuk M. Algorithm and architecture design of the motion estimation for the H.265/HEVC 4K-UHD encoder. J Real-Time Image Process 2015; 12: 517-529.
5. Methenitis S, Terzis G, Zaras N. Intramuscular fiber conduction velocity, isometric force and explosive performance. J Human Kinetics 2016; 50: 93-101.
6. Borges LS, Fernandes MH, Schettino L. Handgrip explosive force is correlated with mobility in the elderly women. Acta Bioeng Biomech 2015; 17: 145-150.
7. José F, Gallego L, Jesús A. Evaluación de la fuerza explosiva de extensión de las extremidades inferiores en escolares. Evaluation of the Explosive Force of Lower Limb Extension in Schoolchildren. Apunts Educacion Fisica Y Deportes 2015.
8. Ivanovic J, Dopsaj M, Copic, Nemanja. Is there a relation between maximal and explosive leg extensors isometric force?. Facta Universitatis 2011.
9. Lange B, Bury T. Physiologic evaluation of explosive force in sports. Rev Med Liege 2001; 56: 233-238.
10. Wilcox J, Larson R, Brochu KM. Acute explosive-force movements enhance bench-press performance in athletic men. Int J Sports Physiol Performance 2016; 1: 261-269.
11. Mahmood Z, Ali T, Khattak S. Automatic player detection and identification for sports entertainment applications. Formal Pattern Anal Appl 2015; 18: 971-982.
12. Ebert JR, Smith A, Fallon M, Butler R, Nairn R. Incidence, degree, and development of graft hypertrophy 24 months after matrix-induced autologous chondrocyte implantation: association with clinical outcomes. Am J Sports Med 2015; 43: 2208-2215.
13. Gonzalez AM, Hoffman JR, Wells AJ. Effects of time-release caffeine containing supplement on metabolic rate, glycerol concentration and performance. J Sports Sci Med 2015; 14: 322-332.
14. Secomb JL, Sheppard JM, Dascombe BJ. Time-motion analysis of a 2-hour surfing training session. Int J Sports Physiol Performance 2015; 10: 17-22.
15. He W, Xu G, Rong Z. Automatic Calibration System for Digital-Display Vibrometers Based on Machine Vision. Metrology Measurement Syst 2014; 21: S87-S88.
16. Siergiejczyk M. Issues Regarding Information Safety in Digital Network of Railway Radio Communications/ Zagadnienia Bezpieczenstwa Informacyjnego w Sieci Cyfrowej Radiolacznosci Kolejowej. J Konbin 2015; 33: 169-176.
17. Omorkiewicz M, Kryjak T, Chuchacz-Kowalczyk K. FPGA based system for real-time structure from motion computation. Design and Architectures for Signal and Image Processing, IEEE, 2015.
18. Ranger BJ, Feigin M, Pestrov N. Motion compensation in a tomographic ultrasound imaging system: Toward

volumetric scans of a limb for prosthetic socket design. Eng Med Biol Soc IEEE 2015; 2015: 7204-7207.
19. Bhakti TL, Susanto A, Santosa PI. Design of Automated Moving Stage with Adaptive Focus System to Support Microscopy Image Stitching. Appl Mech Materials 2015; 780: 55-68.

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