

VISUAL SENSOR-BASED OBSERVATION AND IMAGE ANALYSIS OF MUSCLE INJURIES IN ATHLETES

OBSERVAÇÃO E ANÁLISE DE IMAGEM BASEADA EM SENSORES VISUAIS DAS LESÕES MUSCULARES EM ATLETAS

OBSERVACIÓN Y ANÁLISIS DE IMÁGENES BASADO EN SENSORES VISUALES DE LESIONES MUSCULARES EN DEPORTISTAS



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ABSTRACT

Introduction: Athletes and fitness enthusiasts often suffer muscle injuries during their training. These injuries can worsen when not treated properly, generating an accumulation of severe tissue damage, preventing optimal physical performance, and impacting low immunity. Despite a large number of researches on muscle injuries, its vast majority is limited to the pathological perspective, and there are few studies related to the specific impact of the body sport muscle injury index. **Objective:** Analyze the body-specific indicators of sports injury to prevent further damage to its practitioners. **Methods:** Laser scanning confocal electron microscopy is the main observation tool in studying muscle injury in athletes. In further research, an experimental animal model was established. The test samples were 40 male rats over 12 weeks old, randomly divided into four groups, treadmill exercise, swimming at 8% of the weight, and other sports training items. **Results:** Through the comparative experiment of three indicators, it is found that muscle damage has a widespread impact on the whole body, particularly on blood serum indicators. The period of one hour after injury is considered to have the most impact. However, the symptoms subside after 24 hours. **Conclusion:** As the main observation tool in this experiment, the microscope showed its good prospect of application in the field of biomedicine. **Level of evidence II; Therapeutic studies - investigation of treatment outcomes.**

Keywords: Diagnostic Imaging; Sports Injuries; Models, Animal.

RESUMO

Introdução: Atletas e entusiastas adeptos ao condicionamento físico frequentemente sofrem lesões musculares durante seus treinamentos. Essas lesões podem se agravar quando não tratadas adequadamente, gerando um acúmulo de danos teciduais graves, impedindo o desempenho físico ideal e impactando na baixa imunidade. Apesar do grande número de pesquisas sobre lesões musculares, sua vasta maioria é limitada à perspectiva patológica e há poucos estudos relacionados ao impacto específico do índice de lesão muscular esportivo corporal. **Objetivo:** Analisar os indicadores específicos corporais da lesão esportiva dedicados a evitar maiores danos em seus praticantes. **Métodos:** A microscopia eletrônica confocal de varredura a laser é a principal ferramenta de observação no estudo da lesão muscular em atletas. Nas pesquisas adicionais, um modelo animal experimental foi estabelecido. As amostras de teste eram 40 ratos machos com mais de 12 semanas de idade, divididos aleatoriamente em quatro grupos, incluiu-se o exercício em esteira, natação com 8% do peso e outros itens de treinamento esportivo. **Resultados:** Através da experiência comparativa de três indicadores, constata-se que o dano muscular tem um impacto generalizado sobre todo corpo, particularmente nos indicadores do soro sanguíneo. O período de uma hora após a lesão é considerado como o mais impactante. No entanto, os sintomas diminuem após 24 horas. **Conclusão:** Como principal ferramenta de observação neste experimento, o microscópio mostrou sua boa perspectiva de aplicação no campo da biomedicina. **Nível de evidência II; Estudos terapêuticos - investigação dos resultados do tratamento.**

Descritores: Diagnóstico por Imagem; Lesões Esportivas; Modelos Animais.

RESUMEN

Introducción: Los deportistas y entusiastas del condicionamiento físico suelen sufrir lesiones musculares durante sus entrenamientos. Estas lesiones pueden empeorar cuando no se tratan adecuadamente, generando una acumulación de daños graves en los tejidos, impidiendo un rendimiento físico óptimo y repercutiendo en la baja inmunidad. A pesar del gran número de investigaciones sobre las lesiones musculares, su gran mayoría se limita a la perspectiva patológica y hay pocos estudios relacionados con el impacto específico del índice de lesiones musculares en el deporte corporal. **Objetivo:** Analizar los indicadores corporales específicos de las lesiones deportivas dedicadas a prevenir mayores daños a sus practicantes. **Métodos:** La microscopía electrónica confocal de barrido láser es la principal herramienta de observación en el estudio de las lesiones musculares en los atletas. En otras investigaciones, se estableció un modelo animal experimental. Las muestras de prueba fueron 40 ratos macho de más de 12 semanas de edad, divididas aleatoriamente en cuatro grupos, en los que se incluyó el ejercicio en cinta rodante, la natación con un 8% de peso y otros elementos de entrenamiento deportivo. **Resultados:** A través del experimento comparativo



de tres indicadores, se comprueba que el daño muscular tiene un impacto generalizado en todo el organismo, especialmente en los indicadores del suero sanguíneo. El período de una hora después de la lesión se considera el más impactante. Sin embargo, los síntomas disminuyen después de 24 horas. Conclusión: Como principal herramienta de observación en este experimento, el microscopio mostró sus buenas perspectivas de aplicación en el campo de la biomedicina. **Nivel de evidencia II; Estudios terapéuticos - investigación de los resultados del tratamiento.**

Descriptor: Diagnóstico por Imagen; Lesiones Deportivas; Modelos Animales.

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INTRODUCTION

Athletes and fitness enthusiasts commonly experience three types of pain during daily training and exercise. If not handled properly, it can easily lead to physical injury and damage accumulation. This exercise-induced muscle damage can lead to muscle dysfunction and decreased muscle performance. Therefore, active rehabilitation measures should be taken after daily training and competition.

EIMI refers to the micro-injury of skeletal muscle fibers that occurs after the human body is not adapted to high-intensity exercise or long-term exercise, often manifested as DOMS. DOMS is a muscle soreness phenomenon. The degree of muscle pain is related to the intensity and duration of muscle activity and the form of skeletal muscle contractions.

When analyzing the application of microscope in the field of biomedicine, this paper takes the representative confocal microscope as the main research object. In order to further study the practical application of microscope in EIMI, a muscle injury observation model was established with rats as experimental samples. According to the research data, if the exercise intensity is high enough and the time is long enough, EIMI may be produced in different exercise training, and EIMI has a certain effect on various indicators in the serum, but with the passage of time, the effect will gradually weaken.¹⁻³

METHODS

Study type

Key project of the Ministry of Education in the 13th Five-Year Plan of National Education science. General Research Group on "Developing the change of Teaching Form in Innovation Research". "Construction of high efficiency Classroom of Junior middle school physical education under core accomplishment". The study and all the participants were reviewed and approved by Ethics Committee (NO. YJ1002168).

Visual Perception Algorithm

RGBD Visual Fusion

In the pixel coordinate system, each pixel coordinate stores the color information of each corresponding position object in the space.^{4,5} The imaging plane is built on the actual physical imaging sensor plane inside the camera.⁶ The conversion relationship between the pixel coordinate system.

Image Preprocessing

According to the CMOS noise model given in the previous section, the influence of noise in the CMOS image sensor acquisition system on the image matching and detection results can be easily studied. Here is a simple comparison-normalized reverse mean absolute difference sum (NISAD), normalized reverse mean variance sum (NISSD), normalized reverse maximum absolute difference (NIMD), normalized direct correlation (NDC) And normalized cross-correlation (NCC) these similarity measures change under the influence of noise.^{7,8}

First, give the definition of the above measures:

$$\text{NIASAD}(i,j)=1-\frac{1}{PQ}\sum_z\sum_f|Q(Z,F)-I(i+Z,j+F)| \quad (1)$$

$$\text{NIASAD}(i,j)=1-\frac{1}{PQ}\sum_z\sum_f(Q(Z,F)-I(i+Z,j+F))^2 \quad (2)$$

$$\text{NDC}(I,J)=\frac{\sum_z\sum_fQ(Z,F)I(i+Z,j+F)}{\sqrt{\sum_z\sum_fQ^2(Z,F)\sum_z\sum_fI^2(i+Z,j+F)}} \quad (3)$$

$$\text{NDC}(I,J)=\frac{\sum_z\sum_f(T(Z,F)-\bar{T})I(i+Z,j+F)-\bar{I}(i,j)}{\sqrt{\sum_z\sum_f(T(Z,F)-\bar{Q})^2\sum_z\sum_fI(i+Z,j+F)-\bar{I}(i,j)}} \quad (4)$$

Mean value method is a linear processing method to eliminate image noise. The basic idea is to use the average value of the pixel gray levels in the neighborhood to replace the gray level of the center pixel. The calculation formula is as follows:

$$\bar{I}(x_0,y_0)=\frac{1}{\text{num}}\sum_{(x,y)\in N_0}I(x,y) \quad (5)$$

Where num is the number of pixels in the neighborhood this method is simple and fast, and can effectively eliminate Gaussian noise, so it is still a common denoising method.⁹ The disadvantage is that it severely destroys the edges of the image and blurs the image, which is actually a common defect of all linear filtering algorithms.¹⁰ The improvement of the mean value method is mainly based on the optimization of the weight value, which is called the weighted mean value method, and its expression is as follows:

$$\bar{I}(x_0,y_0)=\frac{1}{\text{num}\sum_{(a,b)\in N_0}w(x,y)}\sum_{(x,y)\in N_0}w(x,y)I(a,b) \quad (6)$$

Where $w(x,y)$ is the weight.

Concerning the choice and refinement of priorities, it mainly concentrated on relevance in space and relevance in gray scale.

$$w(x,y)=\frac{1}{\sqrt{(x-x_0)^2+(y-y_0)^2}} \quad (7)$$

$$w(x,y)=\frac{1}{2\pi\sigma^2}e^{-\frac{(x-x_0)^2+(y-y_0)^2}{2\sigma^2}} \quad (8)$$

The bilateral filtering method is a weighted mean denoising algorithm that combines spatial correlation and gray-scale correlation. Compared with Gaussian weighting algorithms, this algorithm has local feature adaptability and can better retain image edge information. Compared with fuzzy weighting algorithms. No iteration is required, and the amount of calculation is small. Its weight is calculated as shown in formula (9):

$$w(x, y) = e^{-\frac{(x-x_0)^2 + (y-y_0)^2}{2\sigma_D^2}} \times e^{-\frac{(I(x-y) + I(y-y_0))^2}{2\sigma_R^2}} \quad (9)$$

NCC Algorithm

For an image with a size of M×N and a template with a size of P×Q, according to the formula of NCC, it is easy to obtain the addition and multiplication of the order of PQ (M-P+1) (N-Q + 1). It can be seen that when the template size and the image size differ greatly, as the template size becomes larger, the computational complexity of the NCC algorithm will increase by the power. This section starts with the NCC formula, studies the characteristics of each item, optimizes the algorithm structure, and reduces the amount of calculation.

$$\sum_x \sum_y (T(z, f) - q)(I(i+z, f+j) - \bar{I}_{(i,j)}) = \sum_z \sum_f T(z, f)(I(i+z, f+j) - \bar{T}) - \sum_y \bar{T} I(i+z, f+j) \quad (10)$$

It is defined as the value of the pixel point (x, y), which represents the sum of the gray values of all pixels in a rectangular window with the origin (0, 0) and (x-1, y-1) as the diagonal points. As shown in the following formula:

$$I_{\text{integral}}(x, y) = \sum_{i=0}^{x-1} \sum_{j=0}^{y-1} I(i, j) \quad (11)$$

However, the first term of the molecular term is the dot product between the template and the sub-image window, which cannot be solved by the idea of integral image, and this term is actually the direct correlation coefficient between the two matching images. Since the cross-correlation operation of the image in the spatial domain is the smooth movement of the template T on the image I. for convolution, from the frequency domain point of view, it is the complex multiplication operation of the frequency spectrum, so the direct correlation coefficient can be used to transform the image from the fast Fourier transform. The spatial sum is transformed into the frequency domain for calculation, thereby greatly reducing the multiplication and addition operations in the cross-correlation matching.

$$T_F(u, v) = \text{FFT}(T(x, y)) \quad (12)$$

$$I_F(u, v) = \text{FFT}(I(i+x, j+y)) \quad (13)$$

$$\text{Corr}(u, v) = T_F \cdot I_F \quad (14)$$

$$\sum_x \sum_y T(x, y) I(x+i, y+j) = \text{FFT}^{-1}(\text{Corr}(u, v)) \quad (15)$$

As shown in equations (21) and (22), the template T and the original image I are converted into the sum of the frequency domain by FFT, and the complex product of the two obtains the frequency domain expression of the cross-correlation value, and then undergoes inverse fast Fourier transform. The required direct cross-correlation value can be obtained.

Image Observation and Analysis Design of Visual Sensor

The image observation and analysis based on the visual sensor's structure of athlete's muscle injury is shown in Figure 1.

Research on Injury-Causing Factors of Sports Injuries

At the academic level, we divide the risk factors that lead to sports injuries into two categories. Although everyone generally agrees, this category is not comprehensive from the actual situation, because the reasons for human injuries are not only these two aspect.

Breeding and Grouping of Experimental Animals

In this experiment, 40 Yunnan pure male 12 week old rats with good reproduction and development on the same day and close to the same level were randomly divided into 4 groups, 10 rats in each group. The groups of experimental animals are shown in Table 1.

12 week old rats without any treatment were randomly divided into downhill running group, weight-bearing swimming 90 minutes group and blunt force contusion group. All rats were kept in cages for 6 days after purchase. The environment temperature is 20-26 °C, the relative humidity is 47% - 59%. The animals are fed with natural light and free diet according to the national standard rodent feed and distilled water.

Sports Program

1. Animals running downhill

Before the experiment, all the experimental animals had no experience of downhill running. In order to adapt to the treadmill exercise, all the rats in the running group ran on the platform for about 6 minutes two days before the experiment. The experimental animal model of downhill running in this experiment is one of the commonly used animal models of EIMI caused by the increase of exercise load. All the animals ran downhill for 80 minutes at 150 meters per minute. According to the previous research results, the above model can replicate the typical pathological changes of skeletal muscle injury under light microscope, such as myocyte degeneration, necrosis, inflammatory cell infiltration,

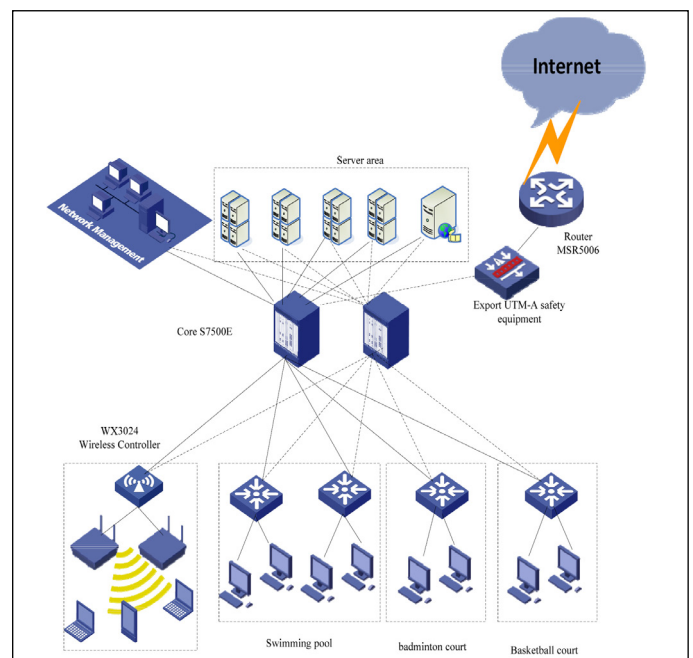


Figure 1. Classification accuracy of decision tree.

Table 1. Weight table of experimental animals.

Group	control group	Running	Swimming	Blunt force
weight	225	210	220	215

etc. The myofilaments of muscle cells are distorted, dissolved and broken, and mitochondria are swollen, broken and dissolved. Therefore, this experimental animal model has laid an experimental foundation for the study of skeletal muscle injury.

2. 8% weight-bearing swimming exercise

In the field of medicine and sports, rat swimming and treadmill running are the most commonly used animal experimental methods. These two methods have their own advantages and disadvantages, but many scholars think that the former method has more advantages, mainly including that rats are born to swim, swimming training, no strong resistance, reduce adverse physical stimulation, which is the least psychological factor of the training method. Mice are trained to run in stimulating or intimidating ways, such as photoelectricity and sound. Studies have shown that electrical stimulation of the skin of a mouse's tail alone can cause physiological changes, such as an increase in noradrenaline and adrenaline. In practice, not all rats can learn to run on the running platform, and it is easy to cause mechanical damage of tail and foot, resulting in bleeding and secondary infection, thus affecting the experimental results. In addition, compared with running on the treadmill, swimming is easier to maintain the exercise intensity at a higher level, and it can also obtain higher exercise intensity than running on the treadmill, and most of the required equipment is ready-made.

According to the experiment of continuous swimming without load, it is found that rats can swim for more than 10 hours or even dozens of hours in the water with suitable temperature. In addition, 8% of the load-bearing rats were able to float continuously for nearly 10 hours at a suitable temperature.

3. Blunt force trauma group

The soft tissue damage hammer was made by ourselves, which was composed of hammer (anvil code), fixed high bar, pad and rat fixed device. During the experiment, the buttocks of the rats were cut off with scissors and fixed on the soft tissue hammer pad with Horizontal method. During the attack, the rats aimed at the soft tissues of buttocks with a 150 g hammer, avoided the leg bones, pulled the hammer to 8 cm high, released the hammer and fell freely.

Comparative Analysis of Muscle Injury Experiment

Analysis of the Influence of Different Interventions on Serum CK

According to the analysis results in Figure 2, the effect of different interventions on CK value varies at different time points. The second peak of serum CK activity was not found under the microscope, and therefore does not reflect the continuous changes in serum CK activity.

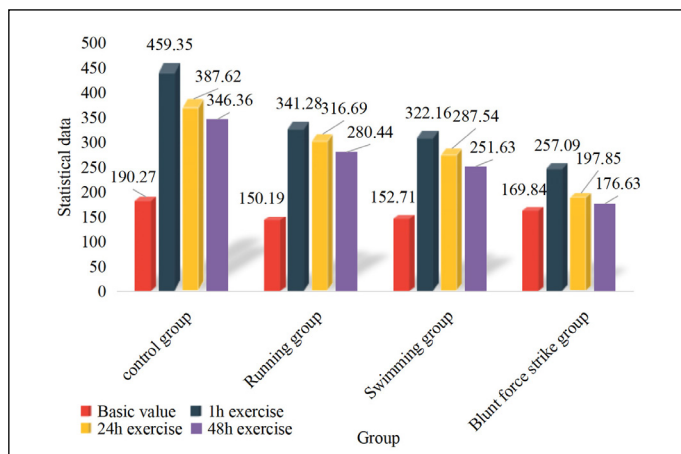


Figure 2. Analysis of the influence of different intervention methods on the CK value of the experimental body

Analysis of the Influence of Different Interventions on Serum LDH

According to the analysis results in Figure 3, different intervention methods had different effects on LDH values in various temporal locations. At baseline time, NO significant changes were observed among the four arms. One hour after exercise, there were significant differences between running group, swimming group and blunt force group ($P < 0.05$), and between swimming group and blunt force group ($P < 0.05$). Through microscope observation, the total activity of LDH in serum of rats in different model groups increased significantly after exercise, but the difference between the groups was statistically significant. The recovery time of swimming group was slower, running group was shorter, and blunt force group was the slowest.

Analysis of the Impact of Various Types of Measures

Based on Figure 4, it can be seen that different intervention methods have different effects on the value of the buns at different time points. Swimming group and blunt force striking group and control group ($P < 0.05$). After 24 hours of exercise, there were significant differences between running group, swimming group and blunt force striking group ($P < 0.05$), and between running group and blunt force striking group and swimming group ($P < 0.05$). The results showed that the serum BUN activity increased after exercise, and the changes of running group and swimming group were more significant than those of blunt force group. However, after 24 hours of recovery, they basically reached the pre exercise state. The change of serum BUN level was more obvious after swimming, which indicated that under the same exercise load, swimming time had a certain effect on the change of serum BUN activity after swimming in rats.

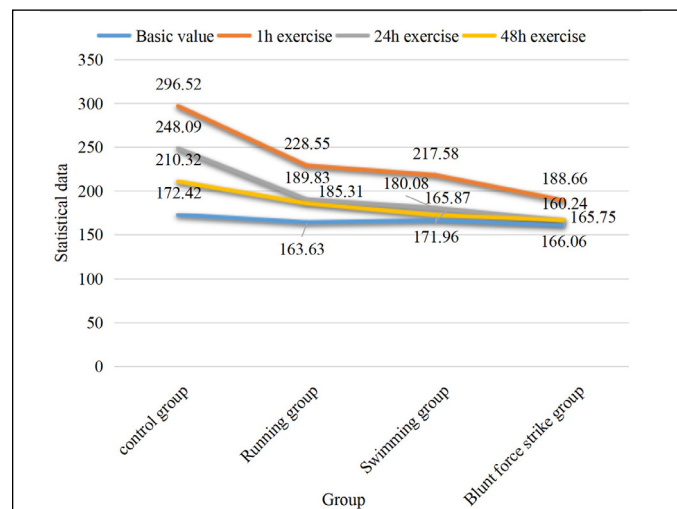


Figure 3. Serum LDH value curve.

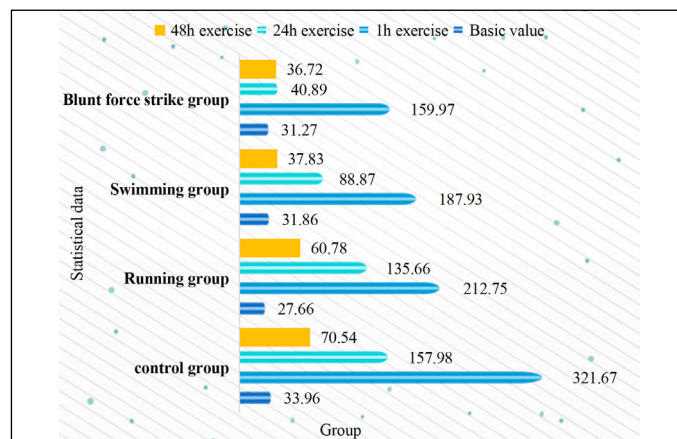


Figure 4. Analysis of the influence of different interventions on the serum BUN value.

Effect of Different Interventions on BLA Value of Blood Lactate

It can be seen from Figure 5 that the change trend of blood lactate level in the three groups is basically the same as that observed under the microscope. The level of blood lactate was significantly higher after exercise than before ($P > 0.05$). But there was no difference among the three groups. Lactate gradually recovered in 1H and 24h after exercise, and there was no difference among the three groups at each time point ($P > 0.05$). There was no significant difference between the two groups in blood lactate recovery, running and swimming at 1 hour after exercise ($P > 0.05$), while the level of blood lactate in blunt force group was significantly higher than that before exercise ($P < 0.05$). The recovery rate of blood lactate can be improved by adding two kinds of sugar.

The Current Situation of Athletes' Sports Injuries

After a survey of athletes of different age groups, it was found that all athletes suffered from sports injuries of varying degrees, with injury

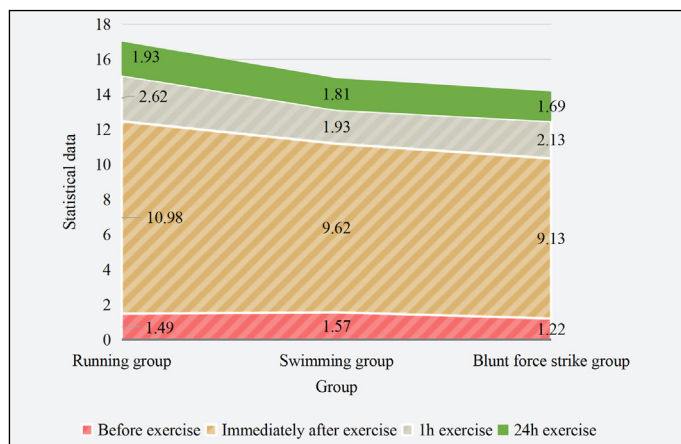


Figure 5. Analysis of Blood Lactate BLA values.

rates as high as 100%. It can be seen that sports injuries are relatively common among athletes. There are different levels according to the degree of loss of athletic ability after sports injuries. According to the actual situation, it can be seen that the number of people suffering from minor injuries is higher, and the number of serious injuries accounts for a relatively small number.

CONCLUSIONS

Since the invention of electron microscope in 1923, it has gradually become one of the necessary tools for most scientific research. In recent years, with the continuous development of microscope field, more and more high magnification microscopes have been developed through different principles, not only the accuracy has been further improved, but also the scope of application of microscopes has become broader. In order to study the application of microscope in the observation of athletes' muscle injury, an animal model was established with laser scanning confocal microscope as the main observation tool. According to the experimental data, different exercise programs can effectively induce motor-induced muscle micro injury, and according to different exercise modes and different exercise intensity, the degree of injury is also different, especially the index including serum LDH value has a strong impact, which further proves that serious muscle injury will bring the disorder of internal environment function and immunity to the body. A drop in force. Through this study, many advantages of microscope in the field of medical observation have been shown again, so this paper thinks that microscope has a broad application prospect in histology, pathology and cytology.

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