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Morphological Changes of Collagen Fibers in Myocardium of Rats under Different Exercise Loads Based on Three-Dimensional Simulation Technique

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Abstract

In order to improve the visual analysis ability of the morphological changes of rat liulimyocardial collagen fibers under different exercise loads, a method of extracting the morphological changes of collagen fibers in rat myocardium under different exercise loads based on three-dimensional simulation technique is proposed. The three-dimensional morphological characteristics of the collagen fibers in the original rat myocardium are made by CT scanning technique. Like information collection, a gradient decomposition method is used to filter the three-dimensional morphological features of rat myocardial collagen fibers. The edge contour features of the three-dimensional morphological features of rat myocardial collagen fibers under different motion loads are extracted. The threshold segmentation method is used to carry out the rat myocardial glue under different exercise loads. The segmentation of the regional pixel feature block of the three-dimensional morphological features of the original fiber is segmented into a block vector with high resolution, and the regional reconstruction of the three-dimensional morphological features of the rat myocardial collagen fibers under different motion loads is carried out to realize the high resolution identification and classification of the 3D morphological features of the rat myocardial collagen fibers. The simulation results show that the three-dimensional simulation of the morphological changes of rat myocardial collagen fibers under different exercise loads is better, and the accuracy of feature extraction is higher.

Keywords 3D simulation technique · Different exercise load · Rat myocardial collagen fiber · Morphological changes

Introduction

Myocardium is composed of cardiomyocytes and myocardial interstitial. The myocardial interstitial is mainly composed of collagen fibers. It is an indispensable component to maintain the structure and function of the heart. Recent studies have shown that myocardial collagen fibers not only support and connect cardiomyocytes, but also play an important role in coordinating the transfer of myocardial muscle strength, transport of nutrients and transmission of information. In the normal group, the collagen network of left ventricle and left papillary muscle is abundant under scanning electron microscope [1]. Collagen fibers are coarse fibers, fine fibers and micro fibers. The number of coarse fibers is relatively small, spanning a number of cardiomyocytes, surrounded by a number of cardiomyocytes, there are longitudinal and transverse directions, longitudinal fiber body parallel, transverse fiber and myocardial cells nearly vertical than cardiomyocytes, In the form of a belt, the cardiomyocytes are bound into bundles. The transverse fibers can be branched or slanted again. The number of fine fibers is more, from the level, it is located in the deep layer of coarse fiber, connected to the coarse fiber, intertwined into a network, the form of the fine fiber is complex and the regularity is not obvious [2].

With the development of digital image processing technology, the use of three-dimensional digital image processing technology for medical image analysis can improve the ability of medical pathological diagnosis and analysis. The three-dimensional morphological feature image of rat myocardial collagen fiber is analyzed by CT light scanning technique, and the 3D morphological characteristic image of rat myocardial collagen fiber is analyzed by CT light scanning technique, and the 3D morphological characteristic image of rat

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myocardial collagen fiber is analyzed by CT light scanning technique [3–5]. The functional state of the heart is one of the important factors that determine the level of exercise training. It is directly related to the quality of sports performance, especially for endurance athletes. The ultrastructural changes of myocardium are observed under different exercise loads. The changes of cardiac ultrastructure can directly reflect myocardial cells and interstitial remodeling. A method of extracting the morphological changes of myocardial collagen fibers in rats under different exercise loads is proposed based on three-dimensional simulation technique [6]. CT scanning technique is used to collect 3D morphological features of rat myocardial collagen fibers. Gradient decomposition method is used to filter the 3D morphological features of myocardial collagen fibers. The edge contour features of 3D morphological features of myocardial collagen fibers in rats are extracted under different exercise loads. The method of threshold segmentation is used to segment the regional pixel feature blocks of 3D morphological feature images of rat myocardial collagen fibers under different exercise loads, and the image is segmented into blocks with higher resolution of feature points. 3D morphological feature images of rat myocardial collagen fibers are reconstructed under different exercise loads to realize high resolution recognition and segmentation of 3D morphological features of myocardial collagen fibers and to extract morphological changes.

Pixel feature acquisition and noise reduction preprocessing of 3D morphological features of myocardial collagen fibers in rats under different exercise loads

Pixel feature acquisition of 3D morphological features of myocardial collagen fibers in rats under different exercise loads

In order to segment the 3D morphologic feature images of myocardial collagen fibers in rats under different exercise loads, a 3D template matching method is used to collect the pixel features [7]. The 3D morphologic features of myocardial collagen fibers are decomposed by adaptive feature decomposition under different exercise loads, and the pixel features of 3D morphological images of myocardial collagen fibers are collected under different exercise loads. The following coordinate system is constructed as:

$$\begin{cases} x = R\sin\eta\cos\phi & 0\leq\phi\leq2\pi \\ y = R\sin\eta\sin\phi & 0\leq\eta\leq\pi \\ z = R\cos\eta & R = D/2 \end{cases} \tag{1}$$

Where, η is the template matching value of 3D morphological feature images of myocardial collagen fibers under different exercise loads in the polar coordinate system, and ϕ indicated the deviation angle of pathological feature points in 3D morphological images of myocardial collagen fibers of rats under different exercise loads. Using Laplace sharpening template matching method, the real-time image of rat myocardial collagen fiber 3D morphology is collected, and the characteristic information of rat myocardial collagen fiber 3D morphological image is extracted. The test set and training set of 3D morphological images of rat myocardial collagen fibers are constructed [8]. This paper analyzes the characteristic quantities of various disease spot states of 3D morphology of rat myocardial collagen fiber, and gives the pixel set of 3D morphological features of myocardial collagen fiber of rats under different exercise loads, the 3D morphologic features of myocardial collagen fiber in rats are expressed as follows:

$$\begin{aligned} J_1(W_i) &= \sum_{r=1}^{t}\sum_{p=1}^{k_1}\left\| W_i^T x_{ir} - W_i^T x'_{irp}\right\|^2 A_{irp} \\ &= \sum_{r=1}^{t}\sum_{p=1}^{k_1} tr\left(W_i^T x_{ir} - W_i^T x'_{irp}\right)\left(W_i^T x_{ir} - W_i^T x'_{irp}\right)^T A_{irp} \\ &= \sum_{r=1}^{t}\sum_{p=1}^{k_1} tr\left(W_i^T\left[\left(x_{ir}-x'_{irp}\right)\left(x_{ir}-x'_{irp}\right)^T A_{irp}\right]W_i\right) \\ &= tr\left(W_i^T\left[\sum_{r=1}^{t}\sum_{p=1}^{k_1}\left(x_{ir}-x'_{irp}\right)\left(x_{ir}-x'_{irp}\right)^T A_{irp}\right]W_i\right) \\ &= tr\left(W_i^T H_1 W_i\right) \end{aligned} \tag{2}$$

Where

$$H_1 = \sum_{r=1}^{t}\sum_{p=1}^{k_1}\left(x_{ir}-x'_{irp}\right)\left(x_{ir}-x'_{irp}\right)^T A_{irp} \tag{3}$$

In order to obtain the corner information of the three-dimensional morphological features of rat myocardial collagen fibers under different exercise loads, the corner information can be simplified in the form of $J_2(W_i)$ by calculating the block characteristic quantities of the images in the x and y directions of the edge scale of the 3D CT imaging, and obtaining the corner information of the three-dimensional morphologic images of the rat myocardial collagen fibers under different exercise loads:

$$\begin{aligned} J_2(W_i) &= \sum_{r=1}^{t}\sum_{q=1}^{k_2}\left\| {W_i}^T x_{ir} - {W_i}^T x_{irq}\right\|^2 B_{irq} \\ &= tr\left({W_i}^T\left[\sum_{r=1}^{t}\sum_{q=1}^{k_2}\left(x_{ir}-x_{irq}\right)\left(x_{ir}-x_{irq}\right)^T B_{irq}\right]W_i\right) \\ &= tr\left({W_i}^T H_2 W_i\right) \end{aligned} \tag{4}$$

Where

$$H_2 = \sum_{r=1}^{t}\sum_{q=1}^{k_2}\left(x_{ir}-x_{irq}\right)\left(x_{ir}-x_{irq}\right)^T B_{irq} \tag{5}$$

3D morphological features of myocardial collagen fibers in rats under different exercise loads are divided into t blocks. The features are separated on x axis and y axis according to the correlation feature information of imaging region:

$$y_i = {W_i}^T M_i = [y_{i1}, y_{i2}, ..., y_{it}] \quad (6)$$

$$y_T = {W_i}^T M_T = [y_{T1}, y_{T2}, ..., y_{Tt}] \quad (7)$$

Based on the results of the above images, Information collection and data set construction of 3D morphological feature images of myocardial collagen fibers in rats under different exercise loadsare implemented on the basis of which 3D morphological feature images of myocardial collagen fibers in rats under different exercise loads are carried out. For neighborhood search and feature matching, Improve the ability of image recognition [9].

Image Noise Reduction Process

The 3D morphological features of rat myocardial collagen fibers are filtered by gradient decomposition method, and the edge contour features of 3D morphological features of myocardial collagen fibers are extracted under different exercise loads [10]. The denoising algorithm of 3D morphological feature image of rat myocardial collagen fiber is based on the threshold denoising method. The prior information of the former 3D morphological feature image of rat myocardial collagen fiber is given, and the wavelet projection mapping method is used. The edge pixel feature W_i of the original image is obtained:

$$W_i = (H_1 - H_2)\omega = \lambda\omega \quad (8)$$

Where, $W = \{w_1, w_2, ..., w_{d_i}\}$ isused to represent the gray vector set of 3D morphological feature images of rat myocardial collagen fibers under different exercise loads in affine invariant region W_i, gradient decomposition method is used, combining with threshold denoising, the output image is obtained:

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X(k) \exp(j2\pi kn/N), n = 0, 1...N-1 \quad (9)$$

By using cascaded wavelet to reduce noise, the location frame of 3D morphological feature image of rat myocardial collagen fiber under different exercise load is obtained as follows:

$$e = \frac{1}{|\nabla u|}\left(\frac{\partial u}{\partial y} i - \frac{\partial u}{\partial x} j\right), f = \frac{1}{|\nabla u|}\left(\frac{\partial u}{\partial x} i + \frac{\partial u}{\partial y} j\right) \quad (10)$$

According to the affine invariant moments of 3D morphologic feature images of myocardial collagen fibers in rats under different exercise loads, $I_x$is the gray pixel sequence of 3D morphological features of myocardial collagen fibers of rats under different exercise loads with a single sample [11]. According to the template matching method, the image Laplace enhancement is performed to improve the information expression ability of the three-dimensional morphological feature image of rat myocardial collagen fibers.

Optimization of feature extraction algorithm for 3D morphological change of image

The gradient-value decomposition method is used to filter the 3D morphological features of rat myocardial collagen fibers. The edge contour features of 3D morphological feature images of rat myocardial collagen fibers are extracted under different exercise loads. The output expression of edge contour sharpening template of 3D morphological features of myocardial collagen fibers in rats under different exercise loads isexpressed as follows:

$$S_c = [S_0, ..., S_{Q-1}]_{binary} = \left[\sum_{i}^{Q-1} S_i \times 2^i\right]_{Dec} \quad (11)$$

The covariance matrix of the distribution of edge contour feature in the three-dimensional morphologic image of rat myocardial collagen fibers under different exercise loads is expressed as follows:

$$C = O^T O \begin{bmatrix} \sum H_x(t) H_x(t) & \sum H_x(t) H_y(t) \\ \sum H_y(t) H_x(t) & \sum H_y(t) H_y(t) \end{bmatrix} \quad (12)$$

According to the scale decomposition in the active contour search region [12], the information enhancement output of the three-dimensional morphological feature image of collagen fibers in rat myocardium under different exercise loads is obtained as follows:

$$O = USV^T \quad (13)$$

The grayscale histogram distribution matrix of 3D morphological feature images of myocardial collagen fibers in rats under different exercise loads is obtained as follows:

$$f_R(z) = \begin{pmatrix} f_x(z) \\ f_y(z) \end{pmatrix} = \begin{pmatrix} h_x * f(z) \\ h_y * f(z) \end{pmatrix} \quad (14)$$

3D morphological features of rat myocardial collagen fibers are segmented under different exercise loads in the active contoured lasso area [13]. 3D morphological features of rat myocardial collagen fibers under different exercise loads are obtained. The edge contour features are extracted as follows:

$$O_i = U_i S_i V_i^T = U_i S_i [v_1, v_2]^{\mathrm{T}} \quad (15)$$

$$v_1 = [v_{11}, v_{12}] \quad (16)$$

The edge contour features of 3D morphological features of myocardial collagen fibers in rats are extracted under different exercise loads. 3D morphological feature extraction method is used to segment the regional pixel feature blocks of 3D morphological feature images of rat myocardial collagen fibers under different exercise loads to improve the feature matching ability and information enhancement performance of the images. 3D morphological features of myocardial collagen fibers in rats under different exercise loads are fused by template matching method. The decomposition equations of the three-dimensional morphological features of myocardial collagen fibers in rats under different exercise loads are described as follows: 1.

$$\left\{ p_{th}^{(b_{int})} = C_t \sum_{x_i \in w} k\left(\|x_i\|\right)\delta(h(x_i)-b_{int})\, p_{te}^{(b_{ine})} = C_e \sum_{x_i \in w} k\left(\|x_i\|^2\right) his_{x_i}\delta(v_{x_i}-b_{ine}) \right. \tag{17}$$

Where, $C_t = C_e = \frac{1}{\sum_{x_i \in w} k\left(\|x_i\|^2\right)}$,by adopting the RGB decomposition method, the image is divided into a block vector with high feature point resolution [14], and the region reconstruction of the three-dimensional morphological feature image of the myocardial collagen fibers of the rat myocardium under different motion loads is performed at the center of the significance feature point to obtain a reconstructed output:

$$\begin{aligned} &E(\phi, f_1, f_2) = \\ &\lambda_1 \int \left[\int K_\sigma(x-y) |I-f_1(x)|^2 H(\phi) dy \right] dx \\ &+\lambda_2 \int \left[\int K_\sigma(x-y) |I-f_2(x)|^2 (1-H(\phi)) dy \right] dx \end{aligned} \tag{18}$$

Where, I^G is dilute thinning of the three-dimensional morphological features of rat myocardial collagen fibers under different exercise loads is expressed, and f_1^G and f_2^G represent the difference values of the pixels in the gradient value, and the pathological analysis is carried out according to the difference of the pixels [15].

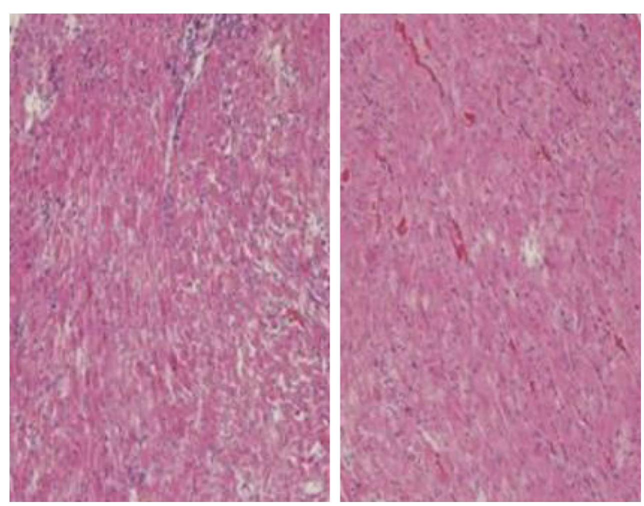
Analysis of simulation experiment

In order to test the application performance of the model designed in this paper to realize the segmentation of three-dimensional morphological feature image of rat myocardial collagen fiber under different exercise load and the high resolution feature location of disease spot, the simulation experiment is carried out. The experiment is designed with Matlab 7, and the parameters are set. The smooth parameter of gradient segmentation is 2.2, the sharpening curvature parameter of rat myocardial collagen fiber 3D morphological feature image under different exercise load is 1.25, the search iteration times is $K = 50$, the sliding matching coefficient of gray-scale histogram is 1.14, and the rat heart. The extraction scale of 3D morphological feature image of muscle collagen fiber is 2, the panel parameter of 3D reconstruction is $\beta = 2.8$, the segmentation scale of nearest neighbor point of super pixel is a= 0.56, the size of template matching is 20*20, and the size of disease spot feature point is 2.5. According to the above simulation environment and parameter setting, the simulation design of 3D morphological feature extraction of rat myocardial collagen fiber under different exercise loads iscarried out. 3D morphological features of collagen fibers in rat myocardium are obtained under different exercise loads as shown in Fig. 1.

Taking the images collected in Fig. 1 as the research object, the three-dimensional morphological features of rat myocardial collagen fibers are filtered to extract the edge contour features of the 3D morphological features of myocardial collagen fibers under different exercise loads. Three-dimensional morphological changes of myocardial collagen fibers in rats under different exercise loads are obtained as shown in Fig. 2.

Figure 2 shows that the accuracy of 3D morphological feature extraction of myocardial collagen fibers in rats under different exercise loads is higher, and the accuracy of morphological characteristics analysis with different methods is tested. The results are shown in Fig. 3.

Figure 3 shows that the accuracy of extracting 3D morphological features of myocardial collagen fibers in rats under different exercise loads is higher than that in exercise overload group, and the change of collagen fiber in exercise overload group is higher than that in overload group. A large number of collagen fibers proliferated in cardiomyocytes and cell groups, and collagen increased significantly from coarse to subdivision levels. The nodules formed from a large bundle of collagen are all composed of fine collagen down, intertwined to form a “reticular” room of cardiomyocytes. Wrapped in



(a) A group (b) B group

Fig. 1 Three-dimensional morphological features of myocardial collagen fibers in rats under different exercise loads

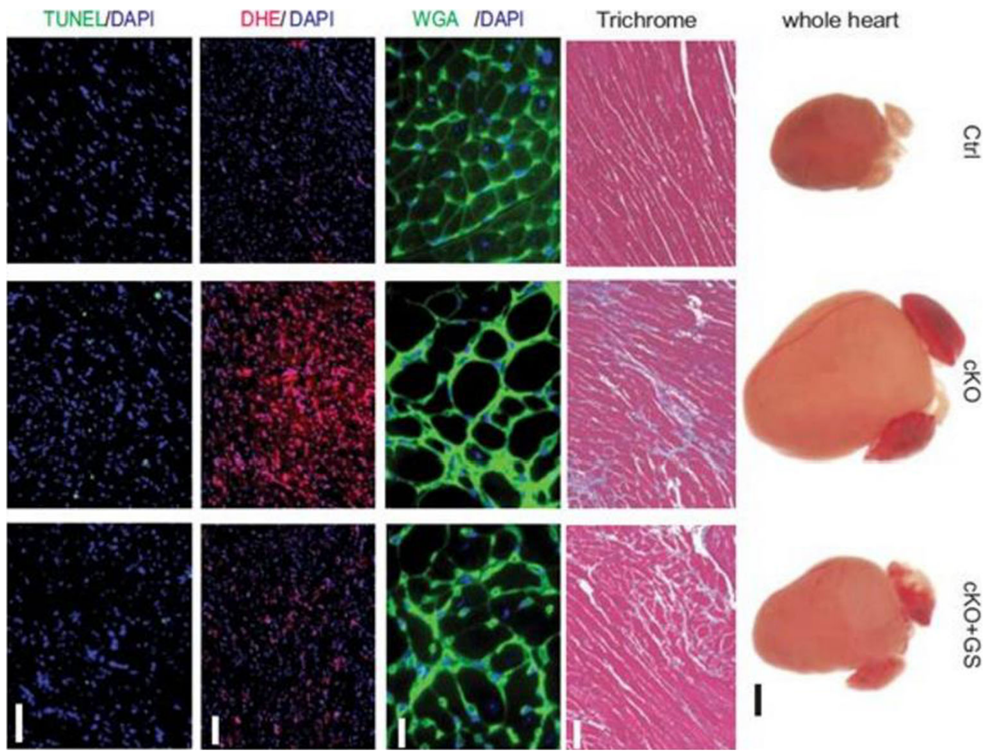


Fig. 2 Distribution of three-dimensional morphological changes of myocardial collagen fibers in rats under different exercise loads

cardiomyocytes, the thick collagen fibers in the interfascicular or hyperproliferative myocardial bundles are wavy, spiral or grid-shaped, and the thickness is obviously graded, and the fine fibers formed obvious meshes. At the same time, it is found that the muscle fiber and collagen fiber broke away in the left papillary muscle. The results showed that exercise overload could induce myocardial collagen fiber proliferation. In general exercise group showed physiological hypertrophy adapted to the enhancement of aerobic metabolic function. Mitochondria increased proportionally with the increase of cell volume and the number of mitochondria increased. The

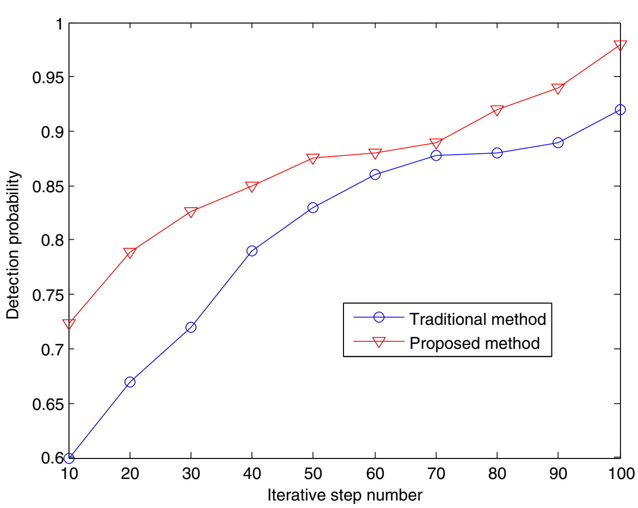


Fig. 3 Comparison of pathological feature estimation of 3D morphological features of myocardial collagen fibers in rats

sarcomere is neatly arranged and more suited to the coordination of rapid cardiac contractions. It can be seen that proper exercise load can improve the function of the heart, on the contrary, long time overload training can damage the heart.

Conclusions

Inthispaper,a method of extracting the morphological changes of collagen fibers in rat myocardium under different exercise loads based on three-dimensional simulation technique is proposed. The three-dimensional morphological characteristics of the collagen fibers in the original rat myocardium are made by CT scanning technique. Like information collection, a gradient decomposition method is used to filter the three-dimensional morphological features of rat myocardial collagen fibers. The edge contour features of the three-dimensional morphological features of rat myocardial collagen fibers under different motion loads are extracted. The threshold segmentation method is used to carry out the rat myocardial glue under different exercise loads. The segmentation of the regional pixel feature block of the three-dimensional morphological features of the original fiber is segmented into a block vector with high resolution, and the regional reconstruction of the three-dimensional morphological features of the rat myocardial collagen fibers under different motion loads is carried out to realize the high resolution identification and classification of the 3D morphological features of the rat myocardial collagen fibers. The simulation results show that the three-dimensional simulation of the morphological changes of rat myocardial collagen fibers under different exercise loads is better, and the accuracy of feature extraction is higher. This method has good application value in the analysis of three-dimensional morphological characteristics of myocardial collagen fibers in rats under different exercise loads.

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