CELL METABOLISM UNDER DIFFERENT INTENSITY EXERCISES IN SPORTS MEDICINE

O METABOLISMO CELULAR SOB EXERCÍCIOS DE DIFERENTES INTENSIDADES NA MEDICINA DO ESPORTE

EL METABOLISMO CELULAR BAJO EJERCICIOS DE DIFERENTES INTENSIDADES EN LA MEDICINA DEL DEPORTE

ORIGINAL ARTICLE
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Lan Zhou[1]
(Physical Education Professional)

1. Department of Physical Education, Northwest University, Xi'an, China.

Correspondence
Lan Zhou
Xi'an 710127, China.
zhoulan201653@163.com

ABSTRACT

Introduction: Articular cartilage is an essential structure for joint weight-bearing and movement. If it is always under a specific mechanical stimulation, it will cause osteoarthritis (OA) and even involve the articular cartilage. Sports can affect articular cartilage thickness, cartilage surface morphology, and cartilage cell metabolism. Objective: This thesis studies the cell metabolism of knee cartilage tissue with exercises of different intensities. Methods: We divided 40 rats into four groups according to exercise intensity. The control group exercised freely, while the experimental group exercised with different intensities. After eight weeks of exercise, we extracted the knee joint cartilage to observe its cell metabolism. Results: We found that the cartilage surface of the rats was complete after exercise, and the thickness of the cartilage layer was significantly greater than that of rats without exercise. Conclusion: Exercises of different intensities have different effects on the metabolism of cartilage cells in the knee joint of rats. ***Level of evidence II; Therapeutic studies - investigation of treatment results.***

Keywords: Sports; Knee joint; Cartilage, articular.

RESUMO

Introdução: A cartilagem articular é uma estrutura essencial para o suporte de peso e movimento de juntas. Quando a articulação está constantemente sob estímulos mecânicos específicos, a osteoartrite (OA) pode resultar, envolvendo inclusive a cartilagem articular. O esporte pode afetar a espessura da cartilagem articular, a morfologia da superfície da cartilagem e o metabolismo celular da cartilagem. Objetivo: Este estudo analisa o metabolismo celular do tecido cartilaginoso do joelho com exercícios de diferentes intensidades. Métodos: Dividimos 40 ratos em quatro grupos de acordo com a intensidade do exercício. O grupo de controle praticou exercícios livremente, enquanto o grupo experimental exercitou com diferentes intensidades. Após oito semanas de exercícios, extraímos a cartilagem da junta do joelho para observar seu metabolismo celular. Resultados: Descobrimos que a superfície cartilaginosa dos ratos se desenvolveu após o exercício, e que a espessura da camada de cartilagem aumentou muito mais do que aquela dos ratos sem exercício. Conclusão: Exercícios de diferentes intensidades tem diferentes efeitos no metabolismo de células cartilaginosas nas juntas de joelhos de ratos. **Nível de evidência II; Estudos terapêuticos – investigação de resultados de tratamento.**

Descritores: *Esportes; Articulação do joelho; Cartilagem articular.*

RESUMEN

Introducción: El cartílago articular es una estructura esencial para el soporte de peso y movimientos de articulaciones. Cuando la articulación está constantemente bajo estímulos mecánicos específicos, puede causar la osteoartritis (OA) e incluso involucrar el cartílago articular. El deporte puede afectar el espesor del cartílago articular, la morfología de la superficie del cartílago y el metabolismo celular del cartílago. Objetivo: Este estudio analiza el metabolismo celular del tejido cartilaginoso de la rodilla con ejercicios de diferentes intensidades. Métodos: Dividimos 40 ratones en cuatro grupos de acuerdo a la intensidad del ejercicio. El grupo de control practicó ejercicios libremente, mientras el grupo experimental ejercitó con diferentes intensidades. Tras ocho semanas de ejercicios, extraemos el cartílago de la articulación de la rodilla para observar su metabolismo celular. Resultados: Descubrimos que la superficie cartilaginosa de los ratones se desarrolló tras el ejercicio, y que el espesor de la camada de cartílago aumentó mucho más que aquella de los ratones sin ejercicio. Conclusiones: Ejercicios de distintas intensidades tienen diferentes efectos en el metabolismo de células cartilaginosas en las articulaciones de rodillas de ratones. **Nivel de evidencia II; Estudios terapéuticos – investigación de resultados de tratamiento.**

Descriptores: *Deportes; Articulación de la rodilla; Cartílago articular.*

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INTRODUCTION

Articular cartilage is an essential structure for joint weight-bearing and movement. If it is always under a specific mechanical stimulation, it will cause osteoarthritis (OA) and even involve the articular cartilage. Sports can affect articular cartilage thickness, cartilage surface morphology, and cartilage cell metabolism.[1] Some scholars have found through epidemiological investigations that running exercise can lead to the occurrence of osteoarthritis. Some scholars compared runners and swimmers and found that moderate-intensity running would not increase knee and hip osteoarthritis incidence. Therefore, the role of exercise in the pathogenesis of osteoarthritis is still controversial.

We used a motorized rat treadmill to study the effects of active exercises of different intensities on normal knee cartilage in rats.[2] Then the article explores the correlation between active exercise and the onset of OA.

METHOD

Experimental animals

There are a total of 40 Sprague-Dawley (SD) male rats. The rat is eight weeks old and weighs 200-220g (SPF grade).

Main instruments

PT98 electric animal treadmill (Shanghai Fengxian Technology Co., Ltd.). Olympus optical microscope camera system (LM) (Japan). HE-600 Transmission Electron Microscope (TEM) (Japan).

Research methods

Grouping of experimental animals

The experimental animals undergo adaptive training for one week, and then we screen out the less adaptable rats. Forty SD rats were randomly divided into a control group, a low-intensity exercise group, a medium-intensity exercise group, and a high-intensity exercise group, with ten rats in each group.[3] The experimental animals were reared in separate cages with natural light and an unrestricted diet. During the experiment, the temperature of the animal feeding environment was 20-23℃, and the relative humidity was 50%-55%.

Exercise intensity

Refer to the Bedford method to determine that the low-intensity group exercise speed is 15m/min, and the medium-intensity group exercise speed is 25m/min. The high-intensity exercise speed is 35m/min. Exercise for 1 hour every day for a total of 8 weeks.[4]

Specimen collection and processing

General observation

The experimental rats were sacrificed after eight weeks. We opened the knee joint to observe whether the knee joint had joint effusion, synovial swelling, and the shape of the articular cartilage surface.

Acquisition and processing of light microscope specimens

In the experiment, the cartilage tissue in the weight-bearing area of the femoral condyle was cut, fixed, decalcified, dehydrated, embedded in paraffin, and sliced for staining.[5] According to the Mankin scoring principle, two independent observers score the slices and take the average of the two as the Mankin score.

TEM specimens

After fixation, decalcification, ultra-thin sectioning, and uranium--lead double staining, the specimen was observed by transmission electron microscope.

Inspection items and methods

1. Hematoxylin-eosin (HE), toluidine blue staining, observation with a light microscope. Under the light microscope, we observe the articular surface of articular cartilage, cartilage cells, cartilage matrix, tide line, and so on.
2. Measurement of cartilage layer and subchondral bone thickness. We take a slice of knee joint tissue and measure the thickness of the cartilage layer and subchondral bone on the slice.[6] The cartilage layer includes hyaline cartilage (from the surface of the cartilage to the surface of the tidal line) and calcified cartilage (from the surface of the tidal line to the junction of the calcified cartilage and bone). Under a 10x light microscope, we select 20 equidistant points with the weight-bearing area of the femoral condyle as the center of each slice. The two points are 400μm apart. We use a 10×10 grid eyepiece micrometer to measure the thickness of each point and each layer. We measured five specimens in each group; each specimen took three fields of view, each field was measured ten times, and finally, the average value was taken.
3. Transmission electron microscope (TEM) observation. The HE-600 transmission electron microscope observes the cartilage surface structure, cells, and fibers.

Action image recognition under high-intensity exercise

In this paper, double convolution theory is used to threshold the original image of the action under high intensity to extract the action image target.[7] Based on this theory, it is necessary to perform *Gabor* wavelet transformation on the action image target under high intensity, which can be expressed as

$$A_{(i,j)}(k,l) = \left\| B(i,j)C(k,l) \right\| \quad (1)$$

$A_{(i,j)}(k,l)$ is a set of filtering results obtained after the action image target is processed by the *Gabor* filter convolution. $B_{(i,j)}$ is the action image target. $C(k,l)$ is the *Gabor* wavelet filter bank. In addition, it is necessary to define the $p+q$central order matrix of the action-image $D(x,y)$ under high-intensity exercise, which can be expressed as

$$E_{pq} = \sum_x \sum_y (x-\bar{x})^p (y-\bar{y})^q D(x,y) \quad (2)$$

$(\bar{x},\bar{y})$ is the center coordinate of the action image. To analyze the action image more accurately, it is necessary to define 4 transform-invariant moments, which are translation, rotation, and scale-invariant moments, which are expressed as follows

$$\begin{aligned} \varphi_1 &= \eta_{20} + \eta_{02} \\ \varphi_2 &= (\eta_{20} - \eta_{02})^2 + 4\eta_{11}^2 \\ \varphi_3 &= (\eta_{30} - \eta_{12})^2 + (3\eta_{21} - \eta_{03})^2 \\ \varphi_4 &= (\eta_{30} + \eta_{12})^2 + (\eta_{21} + \eta_{03})^2 \end{aligned} \quad (3)$$

$\eta_{pq} = \frac{E_{pq}}{E_{00}^{\gamma}}, \gamma = \frac{p+q}{2} + 1, p+q = 2,3,4,\cdots$ represents the normalized center distance of the action-image under high intensity.[8] This paper analyzes the normalized central moments of action images through the classification method of vector machines. Assuming that at any time t, the pixel probability of any pixel (i,j) in the action image is expressed as

$$p(G_{ij}^t) = \sum_{s=K,L} p_s(G_{ij}^t \mid \theta_{ij,s}^t) \quad (4)$$

$G_{i,j}^t$ is the pixel value in the action image at time t. $p_s(G_{i,j}^t \mid \Theta_{i,j,s}^t)$ is the probability of whether the pixel (i,j) of the action-image is the foreground or the background at any time t. The background mixture model of the pixel (i,j) in the action image at any time t can be expressed as

$$p_b(G_{ij}^t) = \sum_k w_{ij,b,k}^t \times \eta(G_{ij}^t, \mu_{ij,b,k}^t, \sum\nolimits_{ij,b,k}^t) \quad (5)$$

k is the number of Gaussian distribution models that express the color characteristics of the action-image pixels in the mixed model. $w_{ij,b,k}^t$ is the weight in the background mixing model of the action-image at any time t, and satisfies $\Sigma w_{ij,b,k}^t = 1$. $\mu_{ij,b,k}^t$ The mean value in the background mixed model at the time t. $\Sigma_{ij,b,k}^t$ is the covariance matrix in the background mixed model at the time t.

The ratio between the weight and the standard deviation is used as the fitness value. It can be expressed as

$$\eta(Y,\mu,\sum)=\frac{1}{(2\pi)^{\frac{\pi}{2}}\,|\sum|^{\frac{1}{2}}}\exp(-\frac{1}{2}(Y-\mu)^{T}\sum{}^{-1}(Y-\mu)) \tag{6}$$

Y and η are the feature vector and the dimension of the feature vector of the action-image pixel (i, j), respectively. μ is the mean value of the conditional probability; Σ is the covariance matrix of the conditional probability.

Statistical analysis

SPSS13.0 software performs statistical analysis on measurement data. Measurement data are expressed as mean ± standard deviation. The t-test was used for comparison between the two groups. The test level $\alpha=0.05$, $P<0.05$ indicates that the difference is significant.

RESULTS

General observation of the specimen

After eight weeks of active exercise training, there was no apparent joint effusion, synovial swelling in the control group and low- and medium-intensity exercise groups. The surface of the articular cartilage was intact without cracks and fibrosis.[9] In the high-intensity exercise group, there was slight joint effusion, synovial swelling, and scattered cracks and fibrotic changes on the articular cartilage surface.

Histological observation and measurement

In the low-intensity exercise group, the cartilage surface was intact, the chondrocytes were arranged regularly, and the nest line was continuous. The cartilage surface was intact in the moderate-intensity exercise group, and the cartilage layer was thickened. The chondrocytes are arranged regularly, and the extracellular matrix secretion of chondrocytes is significantly increased. The nest line is complete and continuous. The cartilage surface was slightly rough in the high-intensity exercise group, and the continuity was partially interrupted.[10] The chondrocytes are partially lost and arranged irregularly, the secretion of the extracellular matrix is reduced, and multiple nesting lines are visible.

Table 1 shows the comparison of the thickness of the knee joint cartilage and the Mankin score of the rats in each group after eight weeks of exercise. This suggests that moderate-intensity active exercise can promote cartilage repair and delay cartilage degeneration, while high-intensity active exercise may promote cartilage damage and degeneration.

Transmission electron microscope observation

In the control and low- and medium-intensity exercise groups, there are apparent circular protrusions on the cartilage surface, continuous membrane-like collagen fibers, active cell proliferation, and more mitochondria. In the high-intensity exercise group, the surface of the cartilage decreases, and part of the surface collagen fibers are exposed. Pyknosis and disintegration of cytoplasm. The specific image information is shown in Figure 1 and Figure 2.

Table 1. Comparison of the thickness and Mankin score of the knee articular cartilage of each group of rats after eight weeks of exercise.

Group	Cartilage thickness (μm)	Mankin score
Control group	263±19	1.62±0.78
Low-intensity exercise group	295±25	1.59±0.56
Moderate exercise group	332±29	1.01±0.31
High-intensity exercise group	189±19	5.12±1.35

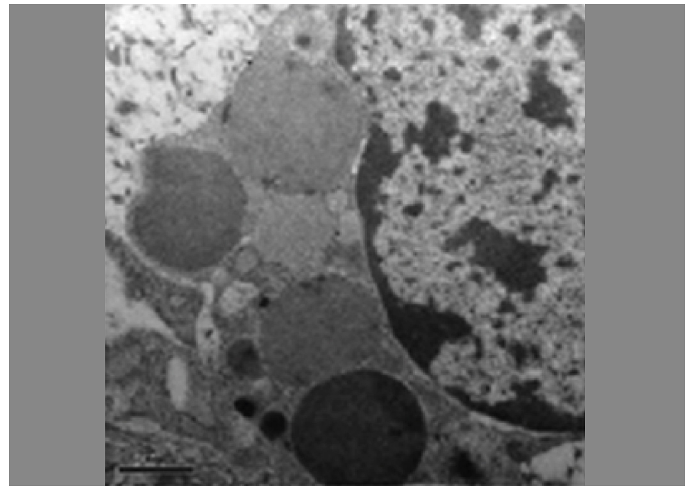

Figure 1. Rat knee cartilage after eight weeks of moderate-intensity active exercise.

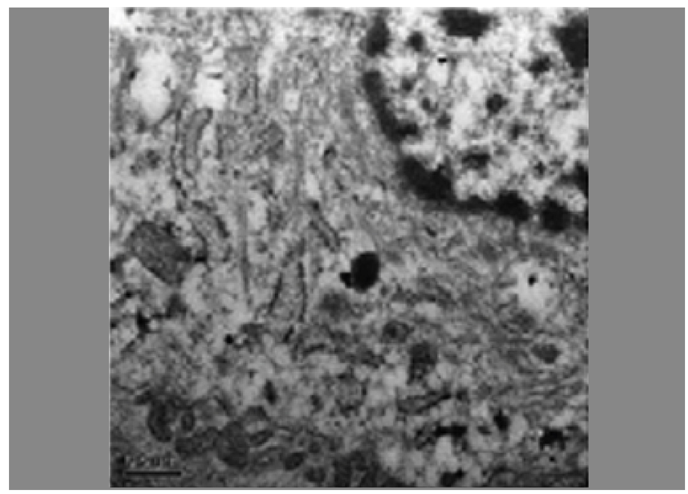

Figure 2. Rat knee cartilage after eight weeks of high-intensity active exercise.

DISCUSSION

Articular cartilage is an essential structure for joint weight-bearing and movement. It plays a vital role in maintaining the normal function of joints. Articular cartilage is composed of cartilage matrix and cartilage cells. The cartilage matrix is mainly composed of proteoglycans and collagen fibers (mainly type II collagen). Cartilage cells are scattered in the cartilage matrix to maintain the normal metabolism of articular cartilage.

Running exercise is one of the essential exercise methods of the human body, and it has an important influence on articular cartilage. Some scholars found that 15 weeks of high-intensity exercise did not cause knee osteoarthritis in dogs. Some scholars have found that high-intensity exercise training can reduce the concentration of canine articular cartilage proteoglycan. Cartilage surface proteoglycan is the most obvious, suggesting that high-intensity exercise has a damaging effect on articular cartilage.[11] Therefore, the effects of active exercise on articular cartilage are still divided. In addition, different exercise methods have different effects on articular cartilage.

In this experiment, compared with the control group, the low-intensity exercise group and the medium-intensity exercise group can increase the thickness of articular cartilage and the concentration of cartilage full-thickness proteoglycan. And it is more evident in the medium-strength group. Some scholars performed moderately running training on experimental mice in a roller, and the results showed that proteoglycan content in cartilage increased and cartilage destruction decreased. Some scholars have found that moderate-intensity active exercise can promote the thickening of articular cartilage in dogs and increase the secretion of full-thickness proteoglycan. The results show that moderate active exercise has a protective effect on articular cartilage. And the greater the intensity of exercise within a specific exercise load, the better the effect. Joint movement plays an essential role in maintaining the normal function of joints. The first is that the metabolism of articular cartilage is inseparable from joint activity. The nutrition of articular cartilage comes from joint synovial fluid produced by joint movement. Secondly, moderate activities can enhance joint function, reduce internal and external adhesions, increase the toughness and strength of surrounding ligaments, joint capsules, and muscles, and enhance joint stability.12

CONCLUSION

Theoretically, articular cartilage may be damaged by two forms of injury, one is sudden trauma, and the other is the damage of articular cartilage caused by repeated activities beyond the capacity of the muscles and ligaments around the joint. Therefore, high-intensity exercise without damaging the bones and joints does not necessarily cause osteoarthritis. Exercise that exceeds the adaptation limit of articular cartilage can directly aggravate cartilage damage and increase the risk of osteoarthritis.

The author declare no potential conflict of interest related to this article

AUTHORS' CONTRIBUTIONS: The author made significant individual contributions to this manuscript. Lan Zhou: writing and data analysis.

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