Effect of HIIT Intervention on Liver Morphology and Liver Triglycerides in Rats Aged 24 Weeks

Ruolin Wang *, HaoSu, Jia Shao
The School of Sports Science, Beijing Sport University, Beijing, 100084, China
*Corresponding Author.

Abstract

Objective:Observing the effects of HIIT intervention on liver morphology and liver triglycerides in naturally aged rats. Methods: 8 month old SPF rats(n=70)were randomly divided into control group (C) and HIIT group (H). Group H exercised alternately with 70% -90% -50% -70% VO2max intensity for 46 minutes / day, 3 days / week, and lasted 24 weeks. Rat liver triglyceride content was tested and liver sections were analyzed. Results: There was a difference in the level of triglycerides between the baseline level of group H and 24 weeks (P = 0.0000); there was no significant difference between the intrahepatic triglycerides of group H rats and that of group C (P> 0.05). The liver triglyceride content of rats in groups C and H showed a steady downward trend. Conclusion: The 24-week HIIT training intervention has a positive effect on the recovery of histological morphology in the liver of naturally aged rats; 24 weeks of HIIT training intervention will not affect the liver triglyceride content of naturally aging rats.
Keywords: HIIT, Rat liver, Liver morphology, Glycerin trilaurate

I. Problems Existing in Current Research

(1) Current studies on liver lipid metabolism mostly focus on the change rules of blood and morphological indicators under high fat diet. There are also some studies on the comparison of lipid metabolism capacity between old and young rats, but they lack the sequential study on liver triglyceride metabolism under natural aging.

(2) Studies on the effect of an exercise intervention on liver lipid metabolism mainly pay attention to aerobic exercise or resistance exercise with moderate intensity, but there is a lack of studies on using HIIT to intervene in and improve triglyceride abnormalities.

(3) There are few studies on the effects of HIIT on liver morphology and triglyceride.

II. Topic Basis

Exercise training is an effective way to prevent and treat chronic diseases, lose body weight, reduce body fat, and improve blood lipid levels. However, at present, most people aren’t willing to exercise due to “lack of time” or “boring feeling” caused by long time exercise. On the other hand, decreased lipid metabolism and abnormal blood TG caused by aging are important reasons for the high incidence of diseases and psychological and physiological problems in middle-aged and elderly people. HIIT movement has variabilityin the exercise process and can overcome the obstacle of “boring”exercise.The objective of this study is to observe the changes of triglyceride and other

ISSN: 0010-8189

indexes in the liver of rats during natural aging with HIIT exercise intervention, expecting to tease out the impact of exercise on improving the triglyceride abnormality caused by aging. This study provides not only a fundamental basis for delaying the abnormal triglyceride induced by aging through HIIT exercise but also a theoretical basis for finding an appropriate method to delay the decline of lipid metabolism during the aging process of the liver.

III. Research Object and Research Method

(1) Research object

In this study, 70 clean0grade male SD rats aged 8 months were selected and randomly divided into two groups: one group was quiet control group (group C) and the other group was HIIT exercise group (group H). The average body weight of group C was 724.01±77.53g, and that of group H was 711.98±72.98g. After statistical examination, there were no statistical differences between the two groups. The grouping is shown in Table 1.

Tab 1: Experimental grouping of rats

Group	Number of rats
Quiet control group	35
HIIT exercise group	35

The feeding environment of both groups of rats was clean, and theirdiet and drinking water were not restricted. The ambient temperature was set as 25 degrees Celsius, and the regular alternating light and dark light was carried out for 12 hours. Group C received no exercise intervention throughout the 24-week experiment. Group H performed HIIT treadmill running.

(2) Test index and test method

1) Determination of rats'exercise intensity

Maximum oxygen uptake test

All rats received adaptive feeding in the animal house for one week, and the first maximal oxygen uptake test was conducted to the rats in group Hto determine the exercise program. After the formal experiment began, the maximum oxygen uptake of rats in group H was tested once every two weeks to adjust the existing exercise program. The maximal oxygen uptake test scheme was improved based on the study of Leandro et al. [20]. The specific test scheme is shown in Table 2.The criteria for determining rats'maximal oxygen uptakewere as follows: 1. Rats could not continue to run normally on the running platform even after receiving electrical stimulation; 2. The VO2max/ first-stage speed difference between the two stages was less than 5%, and the running speed of rats under maximal oxygen uptake was set as the maximum running speed.

Tab 2: Test scheme of rats'maximal oxygen uptake

Grade	Slope (%)	Speed(km/h-1)	Duration (min)
1	10	0.3	4
2	10	0.6	3
3	10	0.9	3
4	10	1.2	3
5	10	1.5	3
6	10	1.8	3
7	10	2.1	3
8	10	2.4	3
9	10	2.7	3
10	10	3.0	3

2) Rats' exercise program

After entering the animal house, all rats needed adaptive feeding for a week, and then the exercise intervention plan of each group was as follows:

Group C: no exercise;

Group H: The maximal oxygen uptake test was conducted every two weeks, and the HIIT exercise program was determined based on the results of rats'maximal oxygen uptake test, and the training was conducted for 24 weeks. The training was usually 46 minutes a day, 3 days a week. The exercise program is shown in Table 3.

Tab 3: HIIT group training program

Stage	Intensity(%VO2max)	Time (min)	Number of times
Warm-up	70%	5	1
High-intensity exercise stage	90%	3	6
High-intensity exercise intermission	50%	3	6
Recovery	70%	5	1

Notes: The average exercise intensity of HIIT training program is 70%VO2max, and lasts 46 minutes for each time.

3) Sampling

Five rats were randomly selected from the quiet control group and the HIIT exercise group after the end of the first test to test each indicator state under the basic state, and then 10 rats were randomly selected from each group 24 hours after the end of the testat the 8th, 16th and 24th weeks after the

maximum oxygen uptake test. The materials are shown in Table 4:

Tab 4: Sampling arrangement of rats

Stage	Group C	Group H
Week 0	5 rats	5 rats
Week 8	10 rats	10 rats
Week 16	10 rats	10 rats
Week 24	10 rats	10 rats

The rats were anesthetized by intraperitoneal injection of 5% chloral hydrate. One liver of rats was exfoliated (the same liver of all rats were exfoliated), and a part of the fresh liver was taken for fresh frozen section fixation to observe the size and number of lipid droplets. A part of the fresh liver was fixed with 4% paraformaldehyde solution for the observation of liver tissue morphology. Then a small piece of the liver sample was cut and put into liquid nitrogen for quick freezing, and then transferred to a low temperature refrigerator for storage, with a temperature of -80℃, and the sample was used for subsequent liver triglyceride content test.

4) Liver triglyceride test

Test index: liver triglyceride of rats

Objective: To reflect the changes of lipid metabolism during natural aging through the changes of triglyceride content in liver.

Test method: The content of triglyceride was measured by enzyme-linked immunoassay. (Shanghai Meilian rat triglyceride ELISA kit was used) First of all, 50mg rat liver was cut and weighed, quantitative PBS and a spoonful of grinding beads were added to it, the liver was ground into a liquid, and centrifuged at 2000-3000 RPM for about 20min. Then the supernatant was collected, and after subpackage, one was taken as the sample to be tested, and the rest was stored in a low-temperature refrigerator at -80℃. After that, standard and sample holes were set up respectively, and samples were added, diluted, and incubated, and a chromogenic agent was added to avoid light for chromogenic determination).

5) Liver morphological index test

Test index: rat liver sections

Objective: To record the changes of the size and quantity change of liver lipid droplets by light microscopy.
Test method:(1) the fresh frozen slices were fixed, and then underwent oil red staining, background differentiation, hematoxylin staining and tablet sealing treatment. The optical microscope was used

for microscopic examination. The images were scanned with a magnification of 400 times, and the image information was observed and recorded.

(2) A leaf of the fresh liver was taken and fixed with 4% paraformaldehyde solution, and after a series of treatments, including dehydrationand transparency, waxdip, paraffin embedding, sliced and pasted, HEstaining, and sealing, it was observed with light microscope. The images were scanned with a magnification of 400 times to observe and analyze liver tissue structure.

Tab 5: Names of main instruments in the experiment

Instruments and consumables	Production place
Small animal treadmill	Columbus Instruments,USA
Small animal gas metabolism analyzer	Columbus Instruments,USA
Multifunctional enzyme marking instrument	Thermo Fisher,USA
Electronic analytical balance	Sartorius,China

Tab 6: Main reagents in the experiment

Kit, reagent	Manufacturer
Shanghai Meilian Rat Triglyceride ELISAS Kit	Shanghai Meilian
Chloral hydrate	China
Liquid nitrogen	China

(2) Statistical approach

A multi-functional microplate analyzer was used to collect data of liver triglyceride, and software Image-Pro Plus 6.0was used to calculate the proportion of lipid droplets in oil-red O staining slices of rat liver. All data were expressed as mean ± standard deviation (X±SD) and analyzed by SPSS21.0 software. Normal distribution was used to test the data, and Kruskal-wallis test was used to analyze the differences between groups C and H at different time points. Mann-Whitney U test was used to analyze the differences between groups C and H at the same time point. The significance level was set as a=0.05, and if $p<0.05$, thenthere would be significant differences. The histological morphology of HE staining slices and oil red O staining slices of the liver was observed by Caseviewer after magnifying 400 times .

IV. Research results

(1) The difference of morphologic changes of rat liver in each group

Figure 1-8 shows the oil red O staining pictures of liver slices of rats in each group. The red is the fat and the blue is the nucleus.

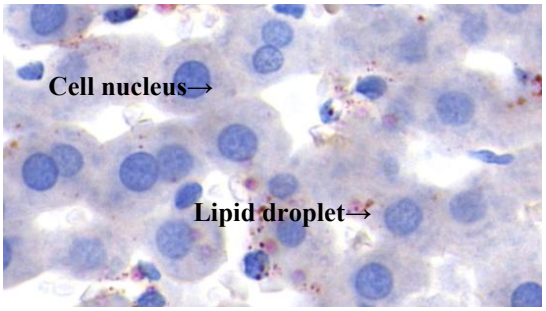

Fig 1: Oil red O staining of rat liver tissue at baseline level (×400)

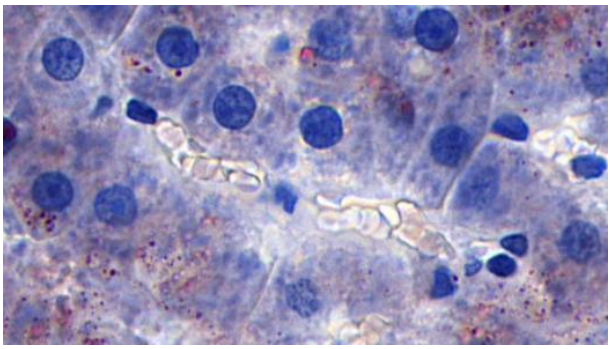

Fig 2: Oil red O staining of rat liver tissue in group Cat week8 (×400)

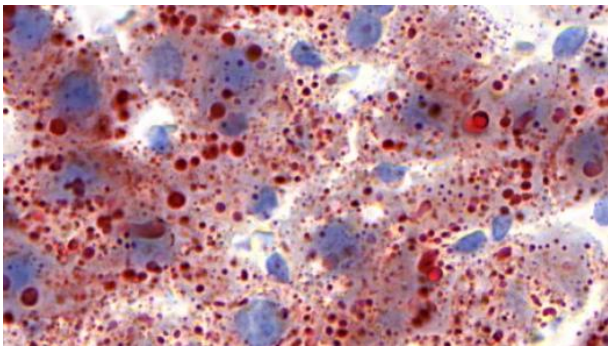

Fig 3: Oil red O staining of liver tissues of rats in group C at week16 (×400)

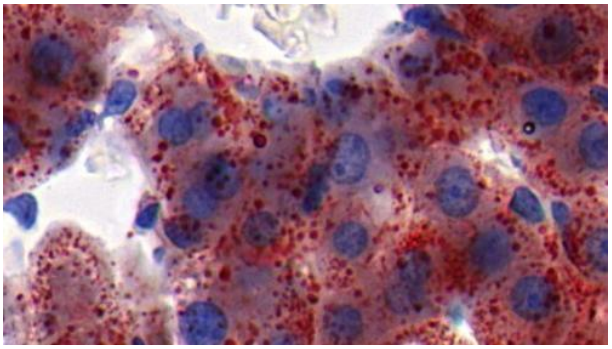

Fig 4: Oil red O staining of liver tissues of rats in Group C at week24 (×400)

As shown in Figure 1-4, with the natural aging of rats in group C, the fat content in liver gradually increased. The liver fat content of baseline rats was the lowest, and that of 24-week-old rats was the highest, indicating that natural aging can cause fat accumulation in the liver of rats.

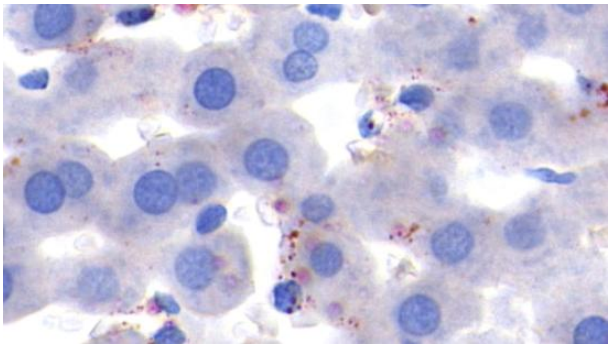

Fig 5: Oil red O staining of rat liver tissue at baseline level (×400)

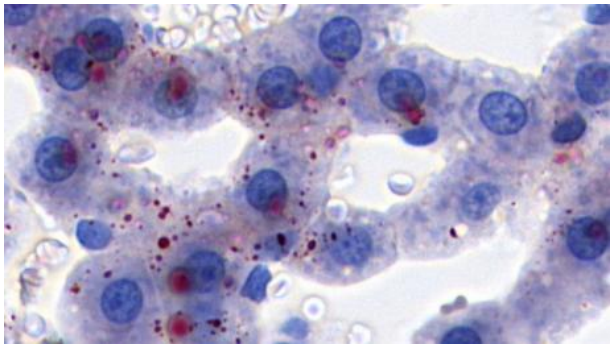

Fig 6: Oil red O staining of rat liver tissue in group H at week8(×400)

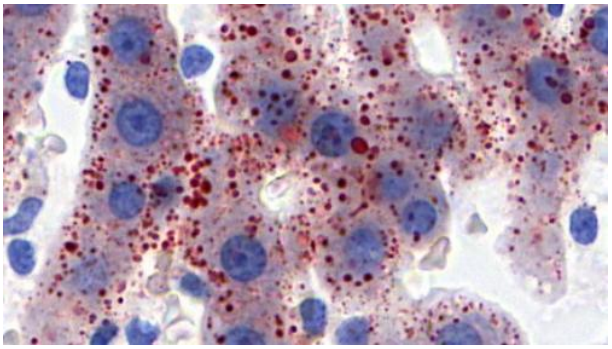

Fig 7: Oil red O staining of liver tissues of rats in group H at week 16 (×400)

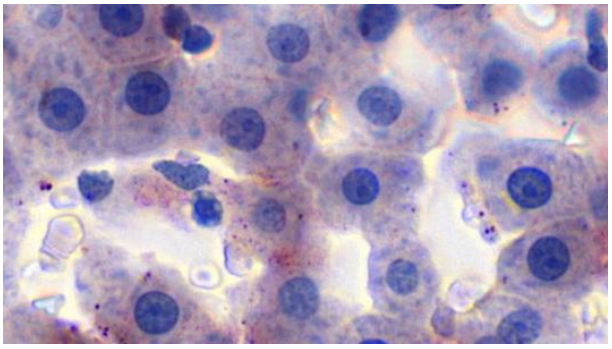

Fig 8:Oil red O staining of liver tissues of rats in Group C at week24(×400)

As shown in Figure 5-8, the fat content in the slices of group H gradually decreased at week 16 and 24, indicating that HIIT could effectively reduce liver fat accumulation. Intra-group comparison showed that at week 16 and 24, the fat content of group H was significantly lower than that of group C, which also indicated that HIIT could reduce the fat accumulation in the liver of rats.

Figure 8-14 shows the HE staining images of liver slices of rats in each group. In biopsy results, liver cell cytoplasm was dyed into purple, blue circular section in the middle of the cytoplasm was the nucleus, the dark bluegranularpartat the edge of cells was lymphocytes, reflecting the inflammatory cell infiltration. Theirregular cavitation among hepatic cells wascaused by ectopic fat accumulation in the liver, which reflected ascavitation in the liver cytoplasm under the microscope when adipose accumulation was severe, making the nucleus deviate to the edge of cells.

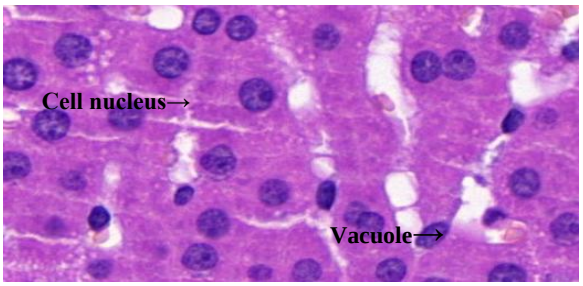

Fig 9: HE staining of rat liver tissue at baseline level (×400)

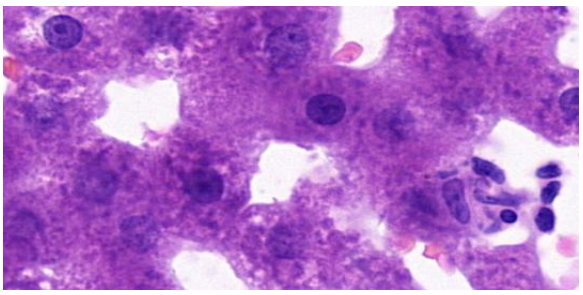

Fig 10: HE staining of rat liver tissue in group C at week8 (×400)

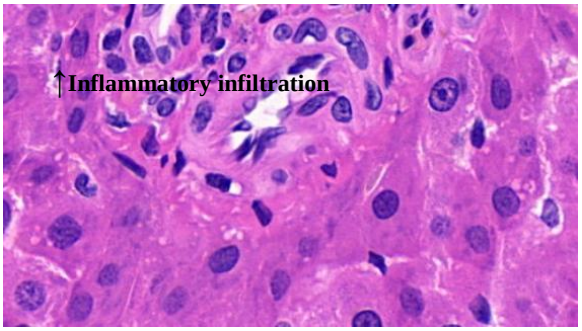

Fig 11: HE staining of liver tissue of rats in group C at week 16 (×400)

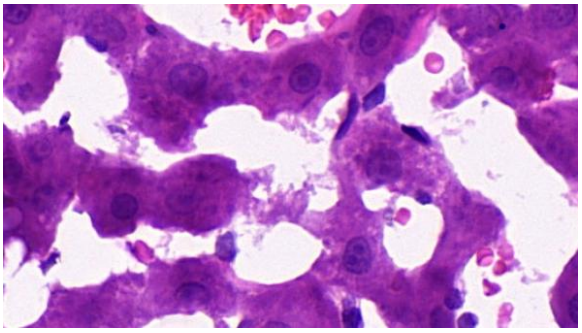

Fig 12: HE staining of liver tissue of rats in Group C at week 24 (×400)

As shown in Figure 9-12, liver slices of rats at a baseline level in group C showed clear lobule structure, round nucleus located in the center of cells, complete and clear nuclear membrane, and clearly visible nucleoli. From week 8 to week 24, the hepatic cell space gradually increased, the contour gradually changed, and inflammatory cell infiltration was also found, which indicated that natural aging could lead to significant changes in the liver morphology of rats.

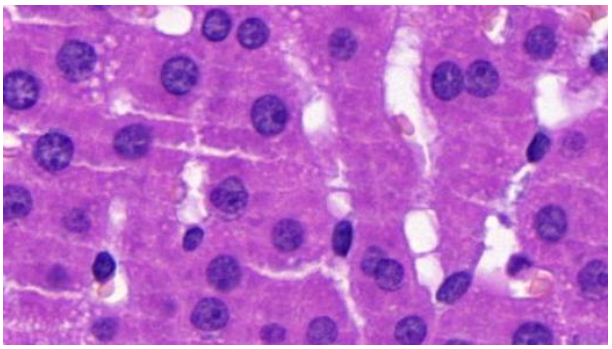

Fig 13: HE staining of rat liver tissue at baseline level (×400)

ISSN: 0010-8189

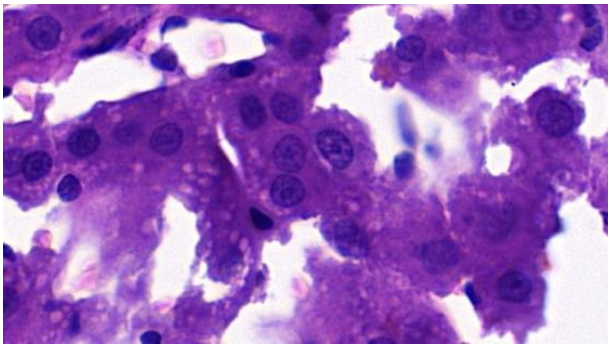

Fig 14: HE staining of rat liver tissue in group H at week 8 (×400)

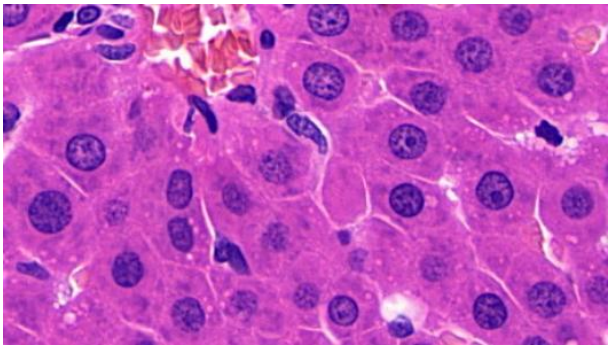

Fig 15: HE staining of liver tissue of rats in group H at week 16 (×400)

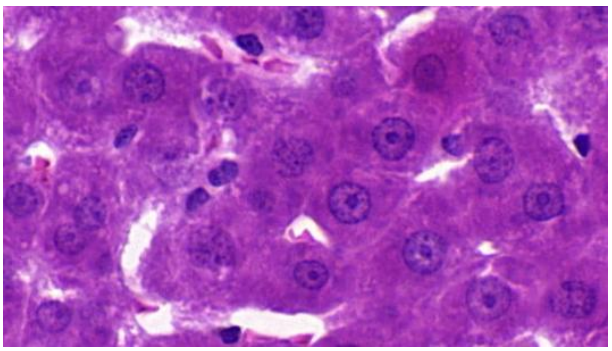

Fig 16: HE staining of liver tissue of rats in group H at week 24 (×400)

As shown in Figure 13-16, compared with group C at week 8, the cell space of group H reduced and the contour of liver cells changed. At week 16, compared with group C, the number of lipid droplets in group H reduced, the occurrence of inflammatory cell infiltration was also reduced, and the cells were arranged more orderly. At week 24, the size and quantity of vacuoles in group H were smaller than those in group C, and the cells were arranged more orderly with almost no inflammatory cell infiltration, but the boundaries between cells were not obvious and almost no lipid droplets, indicating that HIIT had a significant effect on the changes of liver morphology and structure.

Tab 7: Inter-group analysis results of area ratio of liver lipid droplets to slices at each time point

	Group C(%)	TG of group (H%)
Baseline level	3.6094±5.4822	3.6094±5.4822
Week 8	4.3212±1.9858	1.7571±1.8311
Week 16	18.7791±7.9167	2.3846±2.8354#
Week 24	43.9261±8.3215	2.9446±3.7926#

Notes: Area percentage of rat liver fat droplets in section: %
# indicates that the percentage of TG lipid droplets in the area of rats'liver section was significantly different from that of group C without exercise intervention during the same period ($P < 0.05$).

Tab 8: Intra-group analysis results of area ratio of liver lipid droplets to slices of rats in each group

	Baseline level(%)	Week 8 (%)	Week 16 (%)	Week 24 (%)
Group C	3.6094±5.4822	4.3212±1.9858	18.7791±7.9167	43.9261±8.3215#
Group H	3.6094±5.4822	1.7571±1.8311	2.3846±2.8354	2.9446±3.7926

Notes: Area percentage of rat liver fat droplets in section: %
# indicates that the percentage of TG lipid droplets in the area of rats'liver section was significantly different from that of group C without exercise intervention during the same period ($P < 0.05$).

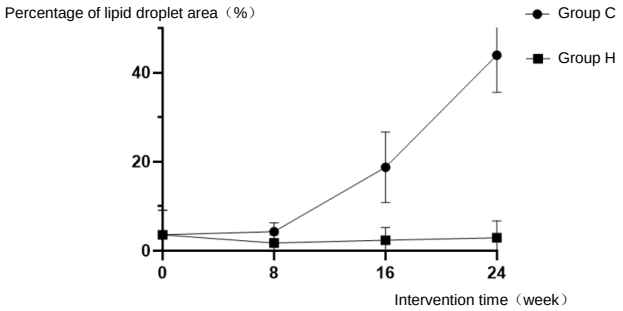

Fig 17: Changing trend of area ratio of liver lipid droplets to slices in each group

As shown in Table 7, there were no significant differences in the area ratio of liver lipid droplets to section area of rats in group H and group C at week 8($P > 0.05$). There were significant differences in the area ratio of liver lipid droplets to section area in group H and group C at week 16 and week 24($P < 0.05$).

As shown in Table 8, the area ratio of liver lipid droplets to slices of rats in group C was different at different weeks. By pairwise comparison, there was a difference in the area ratio of liver lipid

droplets to slices between baseline and 24 weeks (P=0.025). There was a difference in the area ratio of liver lipid droplets to slices between week 8 weeks and week 24 (P=0.047). There was no difference in the rest. (P > 0.05).

As can be seen from Figure 17, the fat content in liver of rats in group C gradually increased with the natural aging. Intra-group comparison showed that at week 16 and week 24, the fat content of group H was significantly lower than that of group C, which also indicated that HIIT could reduce the fat accumulation in the liver of rats.

(2) Changes of liver triglyceride of rats in each group

Tab 9: Inter-group analysis results of liver triglyceride content of rats at each time point

	TG of group C	TG of group H	Z
Baseline level	0.8008±0.3547	0.7344±0.3537	-
Week 8	0.6112±0.2114	0.5370±0.0995	-0.755
Week 16	0.4246±0.0468	0.4498±0.0756	-0.488
Week 24	0.2976±0.0685	0.3180±0.0340	-0.735

Tab 10: Intra-group analysis results of liver triglyceride content of rats in each group

	Baseline TG(μmol/L)	TG at week 8(μmol/L)	TG at week 16	TG at week 24
Group C	0.8008±0.3547	0.6112±0.2114	0.4246±0.0468	0.2976±0.0685##
Group H	0.7344±0.3537	0.5370±0.0995	0.4498±0.0756	0.3180±0.0340##

Notes: # indicates a significant change from baseline level, ## indicates a very significant change.

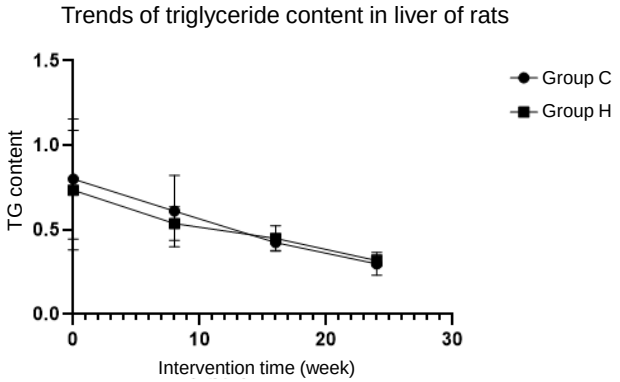

Fig 18: Changing trend of triglyceride content in liver of rats in each group

As shown in Table 9, there were no significant differences in liver triglycerides of rats in group H and group C at week 8, 16 and 24 (P > 0.05).

As shown in Table 10, the intrahepatic triglycerides of rats in group C were different in different weeks. After pairwise comparison, there were differences in triglyceride levelsbetween baseline and week 24 (P=0.000). There were differences in triglyceride levels between week 8 and week 24 (P=0.002). There was no difference in the rest (P > 0.05). In group H, there were differences in hepatic triglycerides in different weeks. After pairwise comparison, there were differences in triglyceride levels between baseline and week 24 (P=0.0000). There were differences in triglyceride levels between weeks 8 and 24(P=0.006). There was no difference in the rest (P > 0.05).

As can be seen from Figure 18, the triglyceride content in liver of rats in group C and group H showed an overall steady decline trend, and group H decreased slowly.

V. Analysis and discussion

(1) Analysis of liver morphology and structure of rats in different groups

In this study, the liver slices of rats were stained with oil red O and HE, respectively. The results showed that with natural aging, the fat content of rats'liver increased, the gap between liver cells gradually increased, the contour gradually changed, and inflammatory cell infiltration was also found, which was consistent with previous studies, indicating that natural aging would cause changes in liver morphology. Organ aging is an irresistible natural lawin the agingprocess. In the aging process of liver, it is mainly manifested as the increased liver weight, the decreased total number of liver cells, the increased volume, and the formation of liver nucleus vacuoles.

In this paper, after HIIT intervention, the size and number of lipid droplets in the liver of rats in group H were smaller than those in group C, and the cell space was reduced, the contour of liver cells was changed and arranged more orderly, and there was almost no inflammatory cell infiltration, which was consistent with previous studies. These results indicated that HIIT intervention affected liver morphology and had a positive effect on liver histological morphology. Currently, there are few studies on the changes in liver morphology caused by HIIT intervention, but it has been confirmed that exercise can influence liver morphology.Studies have shown [22] that aerobic exercise could not only reduce the number of lipid droplets in liver cells but also obviously decrease their morphology. The lobule structure of the liver was clear, the cord structure of liver cells was restored, vacuolar lipid droplets or obvious turbidity and swelling were rare, and inflammatory cell infiltration was reduced compared with the control group.
In conclusion, 24-week HIIT training intervention had a positive effect onliver histological morphology restoration of naturally aging rats.

(2) Analysis of liver triglyceride of rats in different groups

In this study, triglyceride in the liver of rats showed a downward trendwith natural aging, which was inconsistent with previous studies. It can be understood that the metabolic capacity of triglyceride in the liver of rats decreased during the natural aging process, which may be caused by age-related degeneration of the liver. The liver is an important place with the strongest ability to synthesize fat in the body, and triglyceride in the liver can reflect the lipid metabolism in the liver and the whole body

to some extent. Natural aging will affect the triglyceride content in the liver. Studies have shown[24] that the level of TG in the liver of elderly rats is significantly higher than that of young rats.

In this study, the level of liver triglyceride in group H was slightly higher than that in group C at week 8, and the index content in group H was slightly higher than that in group C at weeks 16 and 24. It was speculated that the period from 0 to 8 weeks was an adaptive training for rats, and with the natural aging of rats to 16 weeks, the adaptive training ended, and the synthesis and decomposition of triglycerides began to accelerate, and the metabolic process accelerated. It can be understood that, as the exercise intensity adjusted, the synthesis and decompositionprocess of liver triglycerides accelerated. If the synthesis amount was large, then the decomposition amount would be large, which was a process of dynamic balance. Finally,liver triglyceride of group H at weeks 16 and 24 was slightly higher than that of group C, which indicated that the 24-week HIIT exercise had a certain effect on triglyceride, but the resultswere not significant. It might be due to the short intervention time, so a longer follow-up intervention will be needed to verify whether HIIT exercise has a significant effect on the triglyceride content in the liver of rats.Studies have shown that high-intensity interval training could not only significantly reduce the triglyceride content in the blood[26] of obese youth[25] and patients in the prediabetic state, but also decrease the triglyceride content in the liver of rats[22]. Some studies have pointed out [27] that the triglyceride level of postmenopausal women increased after moderate exercise, and the serum triglyceride content of the elderly increased 24 hours after exercise. [28]

Combined with the morphological structure of the liver, the elevated triglycerides had no direct correlation with liver adipose accumulation, but there was an indirect relationship. Due to the elevated blood lipids, body lipid metabolism declined, which might cause the accumulation of blood lipid on the liver surface, cause the occurrence of fatty liver, which is the main reason for the induction and promotion of fatty liver. Then the complication of high triglycerides may occur.

To sum up, 24-week HIIT exercise intervention had no significant effect on liver triglyceride content.

Acknowledgements
National Innovation and Entrepreneurship Fund for College Students (No. 201910043034).

References

[1] Zou Chenglu. Contemporary Biology [M]. Beijing: Chi Gong Publishing House, 2000.394-6.
[2] Guo Liang, Tang Qiqun. Advances in the pathogenesis and treatment of nonalcoholic fatty liver disease [J]. Life Sciences, 2018, 30 (11): 1165-1172.
[3] Zhang Yanfeng, Jiang Chongmin, Cai Rui. A Study on the Characteristics of Physical Activities in China [J]. Sports Culture Guide, 2012 (10): 26-30.
[4] Idrich. Risk factors for dyslipidemia and association of lipid metabolism genes [D]. Shantou University, 2011.
[5] World Health Organization website. The World Health Organization publishes the Global Report on

Aging and Health [J]. China Health Policy Study, 2015, 8(11): 78-78.
[6] Ye Chengjie. Effects of Different Exercise Modes on Liver Lipid Metabolism in Rats and Its Mechanism [D]. Nanjing Institute of Physical Education, 2018.
[7] Li Longjiang, Yu Yu. Signal transduction pathway of lipid metabolism [J]. Journal of Pediatric Pharmacy, 2005 (01): 7-9.
[8] Kaijie Zhang. Effect of Resistance Training on Liver Lipid Metabolism and Related Gene Expression in Old Mice [D]. East China Normal University, 2013.
[9] Huang Juan. Effect of 8 weeks aerobic plus resistance exercise on fatty liver induced by high-fat diet in mice [D]. Shanghai Institute of Physical Education, 2018.
[10] Blouin K, Despr s J P, Couillard C, et al. Contribution of age and declining and rogen levels to features of the metabolic syndrome in men [J], 2005, 54(8): 1034-1040.
[11] Cankurtaran M, Halil M, Yavuz B, et al. Prevalence and correlates of metabolic syndrome (MS) in older adults[J], 42(1): 35-45.
[12] Timchenko N A. Aging and liver regeneration [J], 20(4): 0-176.
[13] Sun Wenbing, Han Benli, Peng Zhiming, et al. Effects of aging on liver structure and protection of vitamin E in rats [J]. Chinese Journal of Geriatrics, 1997(02): 34-37+65-66.
[14] Li Meng. Study on the Relationship between Total Cholesterol, Triglycerides and Their Dynamic Changes and Metabolic Syndrome [D]. Dalian Medical University, 2018.
[15] Jan Xiaomei, Pan Shanshan, Chen Wenhe. Effect of Exercise Intervention on Body Composition, Lipid, Insulin Resistance and Hypersensitive C-Reactive Protein in Obese Adolescents [J]. Journal of Shanghai Institute of Physical Education, 2012, 36 (06): 62-66.
[16] Yang Zhongya, Suhao, Wang Ji, et al. High intensity intermittent exercise can improve the cardiopulmonary endurance of rats. Tissue Engineering Research, China, 2020: 1708-1713.
[17] Zhang H J, He J, Pan L, et al. Effects of Moderate and Vigorous Exercise on Nonalcoholic Fatty Liver Disease: A Randomized Clinical Trial [J], 2016, 176 (8): 1074-1082.
[18] Effects of different exercise modes on liver lipid metabolism in normal and obese rats and their relationship with FGF21 [C]. 11th National Sports Science Conference, 2019:3.
[19] Liu Nannan, Li Hu, Peng Zonggen. Advances in experimental models and mechanisms of hepatic steatosis [J]. International Journal of Pharmaceutical Research, 2019, 46 (03): 171-175.
[20] Leandro C G, Levada A C, Hirabara S M, et al. APROGRAM OF MODERATE PHYSICAL TRAINING FOR WISTAR RATS BASED ON MAXIMAL OXYGEN CONSUMPTION [J], Journal of Strength and Conditioning Research, 2007, 21(3). 751-756.
[21] Yang Lu, Wang Bingyuan. The basis of liver aging [J]. Chinese Journal of Clinicians, 2015 (3): 7-10.
[22] Wu Xiaoran. Effects of aerobic exercise on liver lipid metabolism and perilipinl protein expression in rats with non-alcoholic fatty liver disease [D]. Hebei Medical University, 2015.
[23] Wang Yi, Mao Rongqiu, Chen Qingyun, et al. Effects of different intensities of aerobic exercise on liver histomorphology in type 2 diabetic rats [J]. Journal of Guangxi Medical University (01): 17-20.
[24] Zeeh J, Platt D J G. The aging liver: structure and functional changes and their consequences for drug treatment in old age [J], 2002, 48(3): 121-127.
[25] Effects of high-intensity interval training and aerobic exercise on lipid metabolism and chronic inflammation in obese young people [J]. Chinese Journal of Sports Medicine, 2017, 36 (07): 628-

632+650.

[26] Effects of high intensity intermittent exercise on glycolipid metabolism in pre-diabetic patients [J]. Chinese Journal of Rehabilitation Medicine (8).

[27] Caballero M J, Maynar M. Effects of physical exercise on sex hormone binding globulin, high density lipoprotein cholesterol, total cholesterol and triglycerides in postmenopausal women[J]. Endocr Res, 1992, 18(4): 261-79.

[28] Murphy, Marie, H., et al. Lipoprotein subfraction oxidation in acute exercise and ageing [J].