Biomedical Signal Acquisition of Hepatobiliary and Portal Vein Before and After Exercise

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Abstract: *In clinical medicine, the research on the hepatobiliary system was proved successfully. In the field of sports medicine, there was little knowledge about the morphological changes, blood distribution, physiological and biochemical as well as pathological changes in the liver, gallbladder and portal vein during exercise. Therefore, studying the function of hepatobiliary system in sports was a problem worthy of attention in sports medicine, and it was also a scientific field that should be urgently studied. Taking exercise-induced abdominal pain as an example, in exercise-induced abdominal pain, the right upper abdominal pain was mainly caused by changes in liver, gallbladder and portal vein. Based on sports medicine, there was little research on the liver, gallbladder and portal vein systems, and the incidence of right upper abdominal pain during exercise was high. The actual mechanism and etiology of the disease still needed to be further confirmed. For this reason, this sports discomfort became the focus of this study. In addition, a safe and effective color Doppler instrument was used to measure the liver and gallbladder and portal vein. The liver, gallbladder and portal vein data before and after exercise were recorded. Based on preliminary experiments and practical results of small samples, it was demonstrated that the liver was ischemic during exercise. It is concluded that this study can lay a foundation for the future research on the liver and biliary portal system, and it is expected to provide safe, non-invasive, reliable, and new indicators for the medical supervision of sports medicine.*

Keywords: *Before and after exercise, Liver, Gallbladder, Portal vein, Color Doppler ultrasound.*

Introduction

In recent years, sports medicine in China has developed rapidly, especially in the field of epidemiology, etiology and pathogenesis of sports diseases. However, in many diversified studies, there is little research on the hepatobiliary and portal system. The liver is a large gland of the human body and has a variety of physiological and biochemical functions. The changes in the liver, gallbladder and portal vein during exercise should be one of the indispensable contents of sports medicine [9]. Based on the above reasons and background, finding a scientific, safe and effective research method to study liver, gallbladder and portal vein during exercise should be an urgent problem to be studied in today’s sports medicine. Exercise affects the liver and causes changes in liver function. Intensive exercise can cause damage to the liver. After strenuous exercise, liver pain is the evident result [7]. The effect on liver function is first reflected in the amount of liver glycogen. Glucose, as the main functional substance, enters the liver after absorption of blood. Heavy load exercise will inevitably lead to a reduction in liver glycogen [2]. Now, it is generally accepted that the cause of motor right upper abdominal pain is the poor preparation exercise, fast speed, incompatible visceral organs and motor organs. Exercise intensity is increased when the function of the viscera has not been raised to the desired level of activity. It is conformed that if the myocardial contraction is poor, it can cause pulsation weakness. At this time, a large number of inferior vena cava blood is obstructed to the heart, and the blood is deposited in the abdominal cavity, liver and spleen. There is no venous valve in the portal vein of the liver. Both ends of the portal vein are capillaries. This anatomical characteristic can not only cause the liver blood flow, will result in melancholy swelling in liver and spleen. Thus, the portal pressure increases. Meanwhile, the liver and spleen are involved in the pain or distention of the membrane [10]. In addition, the pain in the liver and spleen area at early stages of exercise is respiratory rhythm disorder. In strenuous exercise, breathing becomes uneven without rhythm. As a result, breathing becomes superficial. Excessive frequency causes respiratory muscle fatigue and even spasm. The diaphragmatic spasm can cause pain itself. In addition, respiratory muscle fatigue and spasm weaken its massage effect on the liver. At the same time, light breath and high intrathoracic pressure may also hinder the reflux of the inferior vena cava. At the same time, it causes the swelling of the liver and spleen. The other situation is that the liver and spleen cause pain due to membrane stress [5]. The analysis of the imaging before and after human training is an objective requirement for the practice of sports training. To investigate movement-related symptoms such as exercise abdominal pain, exercise hematuria, exercise hemoglobinuria, it is necessary to study the morphology of abdominal, liver, gallbladder, pancreas, spleen, kidney and other internal organs based on medical imaging [4]. There is no doubt that the form is necessarily for functional services. With the development of sports physiology, sports medicine and other disciplines, the understanding of various areas of the human body that are still unclear has become increasingly acute. It still needs more vision, multi-methods and multi-disciplinary analysis of the human body before and after exercise [3]. From the literature search, it is found that Doppler imaging technology has not been reported in the study of hepatobiliary and portal vein in sports medicine and sports training. Therefore, the dynamic observation of imaging morphology of liver, gallbladder and portal vein is selected, which has certain practical significance.

Experimental equipment, object and procedure

Experimental object

There are 10 students in middle and long-distance running in the North China University of Water Resources and Electric Power. All of them participated in system training for many years. There was no previous history of liver disease, and there was no liver injury such as alcohol liver and fatty liver (shown in Table 1).

Experimental equipment

The existing equipment of the Sports Human Body Science Laboratory of North China University of Water Resources and Electric Power is selected. This experiment is done after expert adjustment. The instrument names used in this experiment are shown in Table 2.

Experimental setting

All subjects excluded previous history of liver disease, alcohol liver and fatty liver. Before two days of the test, alcohol should not be allowed two days before the test. Subjects should be tested with an empty stomach.

First, ten athletes with similar body shapes are selected as test samples and the history of previous liver disease should be excluded. Before exercise, the size and width of the hepatobiliary and portal veins were measured by a color Doppler instrument. Then, the liver, gallbladder and portal vein data were detected immediately after running for 5 min, 10 min, 15 min and 20 min on the treadmill. After 20 min of exercise, the data is measured again every 5 min until the measured data and the pre-exercise data are basically the same.

Table 1. Subjects basic registration form

Name	Specialty	Age	Gender	Height, cm	Weight, kg	Liver disease history
Wang XX	middle and long-distance running	22	Male	180	63	No
Li XX	middle and long-distance running	22	Male	177	60	No
Li X	middle and long-distance running	21	Male	174	65	No
Pu XX	middle and long-distance running	23	Male	183	73	No
Sun XX	middle and long-distance running	22	Male	176	62	No
Zhao XX	middle and long-distance running	23	Male	177	66	No
Zhai XX	middle and long-distance running	21	Male	178	72	No
Jin XX	middle and long-distance running	22	Male	172	68	No
Zhang X	middle and long-distance running	24	Male	180	75	No
Shi XX	middle and long-distance running	21	Male	183	77	No

Table 2. Instrument names used in this experiment

Instrument name	Type	Manufacturer
German h/p/cosmos professional sports running platform	Mercury4.0	German
Kaili color Doppler ultrasound diagnostic instrument	SSI-3000	China
Suunto advisor	Polar rs300x	Finland

Before the test, the subjects were required to perform a test scan on an empty stomach. The purpose is to observe the shape and size of the gallbladder. The scanning effect of liver and portal vein will not be affected by the intestinal gas.

First, the subjects were allowed to run on the platform with a target heart rate of 140-160 times/min. After 5 min, the image data was recorded immediately and then rest until the heart rate was restored to quiet level. Then, the subjects who had a quiet heart rate returned to the platform. After running for 10 min with the target heart rate of 140-160 times/min, the image data was recorded immediately and then rest until the heart rate was restored to quiet level. Then, the subjects who had a quiet heart rate returned to the platform. After running for 15 min with the target heart rate of 140-160 times/min, the image data was recorded immediately and then rest until the heart rate was restored to quiet level. The subjects who had a quiet heart rate returned to the platform again. The image data was scanned immediately after running for 20 min with the target heart rate of 140-160 times/min. Then, it was measured once every 5 min at 4 times.

For the accuracy of the data, 3 valid data are recorded each time to prepare the statistics for the following data.

During the test, the subjects are left lateral position and horizontal position. Before and after exercise, the images were frozen when the air was inhaled, and the probe was used to scan the lower edge of the rib arch and record the image data. Using the right clavicular line, the distance from the top of the liver to the lower edge of the liver is taken as the length of the liver. The use of real-time extended imaging is helpful for the correct measurement of the liver, especially when the liver is enlarged. However, it is difficult to measure the liver correctly because of the limited observation range of the real-time sector scan [8]. The optimal state of the liver is shown in Fig. 1 and Fig. 2. The outermost location of the liver is measured.

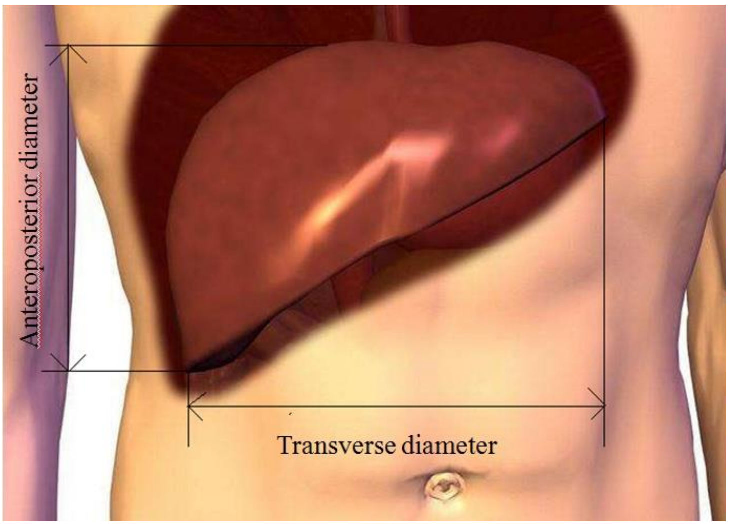

Fig. 1 The transverse diameter and anteroposterior diameter of the liver

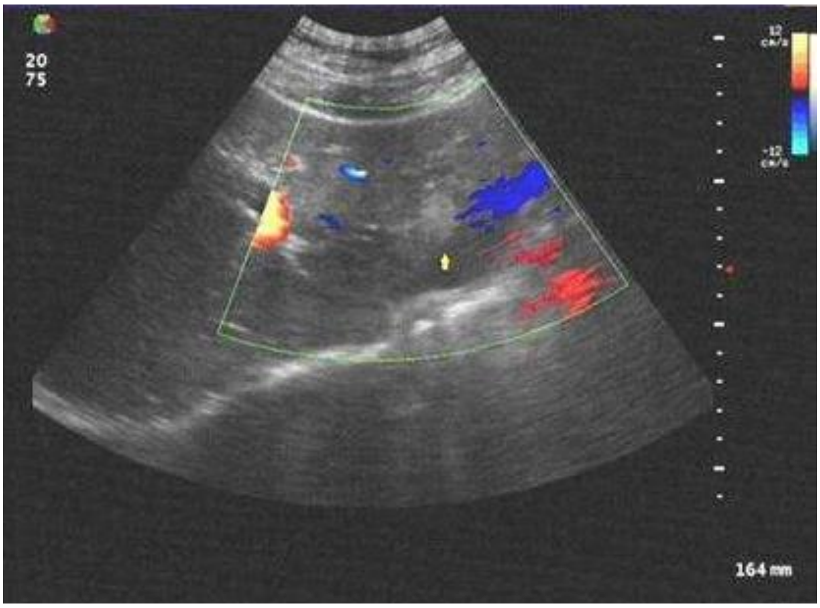

Fig. 2 Actual measurement and positioning of the liver

The maximum width (w, transverse diameter) and height (h, anteroposterior diameter) of the gallbladder were measured on the maximum transverse section. The measuring points of the maximum length (d_{max}) on the longitudinal section are all in the inner wall of the gallbladder [6]. As shown in Fig. 3, the probe was placed on the connecting line between the outer edge of the right rectus abdominis muscle and the costal arch and the umbilicus to measure the inner diameter of the portal vein [1]. The portal vein measurement is shown in Fig. 4.

All experimental data was organized and stored using Microsoft Office Excel 2003. The results are expressed as mean ± standard deviation. The data was further analyzed with SPSS for Windows 11.5 statistical software. $p < 0.05$ indicates that the difference is obvious and is expressed as *. $p < 0.01$l indicates that the difference is very obvious.

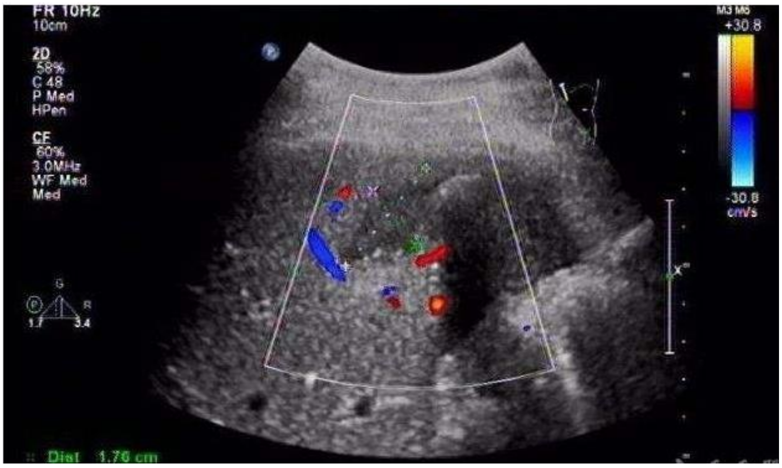

Fig. 3 Gallbladder measurement

Fig. 4 Portal vein measurement

Results and analysis

Data research result

Liver data before and after exercise are shown in Table 3.

Table 3.The maximum diameter (mm) of the liver before and after exercise

Name	Before exercise	5 min	10 min	15 min	20 min
Wang XX	134.15 ± 0.27	131.85 ± 0.47*	126.13 ± 0.34*	124.19 ± 0.37*	124.86 ± 0.32*
Li XX	133.09 ± 0.48	124.55 ± 0.34*	114.58 ± 0.25*	110.24 ± 0.31*	109.30 ± 0.34*
Li X	132.96 ± 0.32	130.01 ± 0.34*	122.18 ± 0.35*	120.44 ± 0.36*	120.60 ± 0.26*
Pu XX	138.34 ± 0.37	135.48 ± 0.43*	133.98 ± 0.32*	130.14 ± 0.34*	130.39 ± 0.27*
Sun XX	143.90 ± 0.32	140.35 ± 0.42*	135.79 ± 0.31*	134.63 ± 0.41*	132.88 ± 0.34*
Zhao XX	141.15 ± 0.48	141.10 ± 0.42	139.47 ± 0.29*	132.99 ± 0.46*	133.44 ± 0.43*
Zhai XX	132.74 ± 0.34	130.19 ± 0.39*	127.84 ± 0.43*	125.99 ± 0.46*	125.57 ± 0.32*
Jin XX	137.35 ± 0.43	132.80 ± 0.37*	130.65 ± 0.34*	127.35 ± 0.56*	130.68 ± 0.35*
Zhang X	131.46 ± 0.40	129.01 ± 0.31*	124.13 ± 0.23*	122.79 ± 0.42*	124.10 ± 0.32*
Shi XX	136.04 ± 0.37	130.57 ± 0.43*	125.47 ± 0.37*	122.10 ± 0.34*	123.18 ± 0.31*

In the comparative analysis of the exercise time of the same subjects, $p < 0.05$ shows that there is obvious difference, expressed by *.

From the experimental data, it is shown that the long diameter of the liver is significantly shortened after exercise. The reduction of the liver is evident from 5 min and 10 min at the beginning of the exercise. The largest number of measured values during the exercise phase was reduced by 1 cm than the value before exercise. Therefore, a large reduction in liver volume can be obtained. A decrease in the volume of the liver can indicate that liver blood is redistributed into the circulatory system after exercise. From 5 min and 10 min at the beginning of the exercise, it is also the time when exercise-related right upper abdominal pain occurs most. Gallbladder data before and after exercise are shown in Table 4.

Table 4. Gallbladder data (mm) before and after exercise

Name	**Before exercise**	**5 min**	**10 min**	**15 min**	**20 min**
Wang XX	70.79 ± 0.41	72.13 ± 0.27	71.38 ± 0.33	72.57 ± 0.35	70.24 ± 0.27
Li XX	53.58 ± 0.27	54.39 ± 0.32	52.10 ± 0.27	53.86 ± 0.41	53.14 ± 0.35
Li X	56.67 ± 0.35	55.25 ± 0.53	53.57 ± 0.37	57.13 ± 0.26	55.59 ± 0.38
Pu XX	36.42 ± 0.25	37.19 ± 0.3	37.23 ± 0.27	35.80 ± 0.37	37.09 ± 0.32
Sun XX	54.82 ± 0.51	52.35 ± 0.37	53.18 ± 0.35	52.67 ± 0.28	52.78 ± 0.41*
Zhao XX	55.56 ± 0.37	57.07 ± 0.41	56.12 ± 0.33	55.87 ± 0.42	57.19 ± 0.30*
Zhai XX	52.35 ± 0.43	55.11 ± 0.33	53.09 ± 0.35	52.09 ± 0.37	54.23 ± 0.31*
Jin XX	43.39 ± 0.26	44.98 ± 0.31	44.03 ± 0.24	44.56 ± 0.37	45.18 ± 0.23*
Zhang X	60.25 ± 0.37	56.33 ± 0.27	58.75 ± 0.38	60.28 ± 0.32	57.78 ± 0.35*
Shi XX	39.44 ± 0.22	42.75 ± 0.35	44.14 ± 0.33	42.90 ± 0.37	41,57 ± 0.36

In the comparative analysis of the exercise time of the same subjects, $p < 0.05$ shows that there is obvious difference, expressed by *.

From the above data, it is found that the changes of gallbladder after exercise are not very obvious, but corresponding rules can also be found: After the start of exercise, gallbladder generally increases accordingly. It can also be stated that while the liver is shrinking, the intrahepatic bile ducts also contract accordingly. Bile excreted in the bile duct enlarges the gallbladder.

The portal vein data before and after exercise are shown in Table 5.

Table 5. The portal vein data (mm) before and after exercise

Name	**Before exercise**	**5 min**	**10 min**	**15 min**	**20 min**
Wang XX	10.34 ± 0.27	11.18 ± 0.33*	12.98 ± 0.37*	12.89 ± 0.47*	12.57 ± 0.31*
Li XX	11.20 ± 0.32	12.78 ± 0.42*	13.93 ± 0.23*	13.89 ± 0.37*	13.40 ± 0.42*
Li X	11.98 ± 0.33	12.99 ± 0.37*	13.52 ± 0.27*	13.79 ± 0.38*	13.58 ± 0.31*
Pu XX	10.22 ± 0.29	11.05 ± 0.33	11.83 ± 0.35*	12.38 ± 0.31*	12.57 ± 0.31*
Sun XX	9.56 ± 0.41	10.35 ± 0.28*	11.24 ± 0.38*	11.68 ± 0.33*	11.79 ± 0.31*
Zhao XX	10.83 ± 0.18	11.33 ± 0.31*	11.57 ± 0.29*	11.78 ± 0.37*	11.80 ± 0.27*
Zhai XX	10.18 ± 0.31	11.08 ± 0.29*	11.43 ± 0.33*	11.64 ± 0.27*	12.05 ± 0.35*
Jin XX	10.20 ± 0.27	10.79 ± 0.31	11.42 ± 0.33*	11.99 ± 0.31*	11.78 ± 0.28*
Zhang X	10.80 ± 0.37	11.33 ± 0.28*	11.74 ± 0.35*	11.67 ± 0.32*	11.99 ± 0.29*
Shi XX	10.52 ± 0.37	11.79 ± 0.35*	12.48 ± 0.41*	12.33 ± 0.31*	12.57 ± 0.24*

In the comparative analysis of the exercise time of the same subjects, $p < 0.05$ shows that there is obvious difference, expressed by *.

After exercise, the portal vein is significantly thickened. This change increases blood flow. The recovery is faster after exercise. The measurement data are shown in Table 6.

Table 6. Liver changes (mm) during recovery after exercise

Name	Sports immediately	5 min	10 min	15 min	20 min
Wang XX	124.86 ± 0.32	130.34 ± 0.37	132.57 ± 0.32*	138.04 ± 0.37*	136.15 ± 0.32*
Li XX	109.30 ± 0.34	131.38 ± 0.31	132.15 ± 0.25*	134.46 ± 0.40*	135.57 ± 0.32*
Li X	120.60 ± 0.26	129.30 ± 0.34	131.04 ± 0.37*	133.35 ± 0.33*	133.96 ± 0.32*
Pu XX	130.39 ± 0.27	130.30 ± 0.32	130.10 ± 0.32*	136.38 ± 0.31*	137.34 ± 0.37*
Sun XX	132.88 ± 0.34	137.14 ± 0.37*	138.46 ± 0.40*	137.57 ± 0.32*	144.90 ± 0.32*
Zhao XX	133.44 ± 0.43	128.57 ± 0.33	130.57 ± 0.32	135.88 ± 0.34	142.15 ± 0.48*
Zhai XX	125.57 ± 0.32	130.57 ± 0.32*	130.37 ± 0.36*	136.36 ± 0.32*	137.73 ± 0.34*
Jin XX	130.68 ± 0.35	130.29 ± 0.38	135.57 ± 0.32*	137.30 ± 0.34*	139.35 ± 0.43*
Zhang X	124.10 ± 0.32	128.45 ± 0.25*	130.34 ± 0.37*	137.38 ± 0.31*	137.46 ± 0.40*
Shi XX	123.18 ± 0.31	128.10 ± 0.32*	130.46 ± 0.33*	135.15 ± 0.35*	138.13 ± 0.37*

In the comparative analysis of the exercise time of the same subjects, $p < 0.05$ shows that there is obvious difference, expressed by *.

The experimental data shows that the maximum oblique diameter of the liver gradually increases after exercise. This shows that after exercise, skeletal muscle and skin participate in exercise blood. At the same time, under the unified deployment of the body, part of the blood is returned to the internal organs for storage. If the liver capsule is pulled when the liver is swollen, it can cause pain. In the recovery period of the liver, there are few reports of right upper abdominal pain.

The gallbladder change after exercise is shown in Table 7.

Table 7. Gallbladder changes (mm) during recovery period after exercise

Name	Sports immediately	5 min	10 min	15 min	20 min
Wang XX	70.24 ± 0.27	70.79 ± 0.41	72.57 ± 0.35	71.63 ± 0.33	71.38 ± 0.33
Li XX	53.14 ± 0.35	53.58 ± 0.27	53.86 ± 0.41	52.35 ± 0.43	52.10 ± 0.27
Li X	55.59 ± 0.38	56.67 ± 0.35	57.13 ± 0.26	52.75 ± 0.33	53.67 ± 0.37
Pu XX	37.09 ± 0.32	36.42 ± 0.24	35.80 ± 0.37	43.39 ± 0.26	37.23 ± 0.27
Sun XX	52.78 ± 0.41	54.82 ± 0.51	52.67 ± 0.28	53.18 ± 0.35	53.18 ± 0.35
Zhao XX	57.19 ± 0.30	55.56 ± 0.37	55.87 ± 0.42	56.12 ± 0.33	56.12 ± 0.33
Zhai XX	54.23 ± 0.31	52.35 ± 0.43	52.09 ± 0.37	56.67 ± 0.35	53.09 ± 0.35
Jin XX	45.18 ± 0.23	43.39 ± 0.26	44.56 ± 0.37	36.42 ± 0.24	44.03 ± 0.24
Zhang X	57.78 ± 0.35	60.25 ± 0.37	60.28 ± 0.32	54.82 ± 0.51	58.75 ± 0.38
Shi XX	41.57 ± 0.36	39.44 ± 0.22	42.90 ± 0.37	45.56 ± 0.37	44.14 ± 0.33

At the end of the exercise, there were no significant changes in the gallbladder during the test period.

The recovery of the portal vein after exercise is shown in Table 8.

During the recovery period after exercise, the diameter of the portal vein shrinks. This should be related to the gradual saturation of blood storage in the liver.

Table 8. Portal changes (mm) during recovery after exercise

Name	Sports immediately	5 min	10 min	15 min	20 min
Wang XX	12.57 ± 0.31	11.83 ± 0.35	12.98 ± 0.37	10.34 ± 0.27*	10.22 ± 0.29*
Li XX	13.40 ± 0.42	11.24 ± 0.38*	13.93 ± 0.23	11.20 ± 0.32*	11.3 ± 0.32*
Li X	13.58 ± 0.31	11.57 ± 0.29*	11.32 ± 0.31*	11.98 ± 0.33*	11.6 ± 0.33*
Pu XX	12.57 ± 0.33	11.43 ± 0.33	11.83 ± 0.35	10.22 ± 0.29*	10.6 ± 0.29*
Sun XX	11.79 ± 0.31	11.20 ± 0.32	11.24 ± 0.38	9.56 ± 0.41*	10.32 ± 0.32*
Zhao XX	11.80 ± 0.31	11.31 ± 0.33	11.57 ± 0.29	10.83 ± 0.18*	11.06 ± 0.18*
Zhai XX	12.05 ± 0.35	10.22 ± 0.29*	11.43 ± 0.33*	10.6 ± 0.31*	10.18 ± 0.34*
Jin XX	11.78 ± 0.28	11.43 ± 0.41	11.42 ± 0.33	10.80 ± 0.27*	10.34 ± 0.33*
Zhang X	11.97 ± 0.29	11.20 ± 0.32	11.74 ± 0.35	11.38 ± 0.37*	10.57 ± 0.28*
Shi XX	12.57 ± 0.24	11.98 ± 0.33	11.48 ± 0.41	10.92 ± 0.34*	10.52 ± 0.37*

In the comparative analysis of the exercise time of the same subjects, $p < 0.05$ shows that there is obvious difference, expressed by *.

Result analysis

The following results are summarized through the above experiment. First, the long diameter of the liver is significantly shortened after exercise. At the 5 min and 10 min from the beginning of the exercise, the liver shrinks very clearly. The largest number of measured values during the exercise phase was reduced by 1 cm than the value before exercise, and a large reduction in liver volume can be obtained. A decrease in the volume of the liver can indicate that liver blood is redistributed into the circulatory system after exercise. From the 5 min to 10 min at the beginning of the exercise, this stage is also the time when exercise-related right upper abdominal pain occurs most. The change of gallbladder after exercise is not very obvious, but corresponding rules can also be found: After the start of exercise, gallbladder generally increases accordingly. It can also be stated that while the liver is shrinking, the intrahepatic bile ducts also contract accordingly. Bile excreted in the bile duct enlarges the gallbladder. After exercise, the portal vein is significantly thickened. This change increases blood flow. Second, after the exercise is over, the maximum oblique diameter of the liver gradually increases. This shows that after exercise, skeletal muscle and skin participate in exercise blood. At the same time, under the unified deployment of the body, part of the blood is returned to the internal organs for storage. If the liver capsule is pulled when the liver is swollen, it can cause pain. In the recovery period of the liver, there are few reports of right upper abdominal pain. After the exercise, the gallbladder changes are still not obvious. However, it is shown that the diameter of the portal vein decreases. This should be related to the gradual saturation of blood storage in the liver.

The change in the liver after exercise is significant. After exercise, the maximum oblique diameter of the liver before exercise is reduced by about 1 cm. In the subject, there is no exercise right upper abdominal pain. All subjects have the same appearance, and the liver and portal vein change significantly after exercise. These changes in form will inevitably bring about some changes in function. Because the subject is a human body, this change can only be described with images. In the future, the physiological and biochemical indexes are analyzed. Therefore, the research of hepatobiliary and portal vein is more specific before and after the exercise.

From this, it is concluded that the blood stored in the liver is distributed to the body's moving organs due to redistribution of blood after exercise, resulting in a reduction in the volume of the liver. The gallbladder has a reflex contraction due to stress. The portal is widened due to transportation needs. The exercise intensity and the body's demand for blood also increase. Blood flow speeds up and the liver continues to shrink. To ensure its own function, it is no longer reduced when it reaches a certain level. After stopping the exercise, the required blood volume of the exercise system is reduced, and the liver gradually returns to its original state due to its blood-storing function. The gallbladder does not change much and the portal diameter decreases.

Conclusion

A safe and effective color Doppler instrument is used to measure hepatobiliary and portal vein. The data of 10 subjects of hepatobiliary and portal vein is recorded and analyzed before and after exercise. The research result shows that the blood stored in the liver is distributed to the body's moving organs due to redistribution of blood after exercise, resulting in a reduction in the volume of the liver. The gallbladder has a reflex contraction due to stress. The portal is widened due to transportation needs. The exercise intensity and the body's demand for blood also increase. Blood flow speeds up and the liver continues to shrink. To ensure its own function, it is no longer reduced when it reaches a certain level. After stopping the exercise, the required blood volume of the exercise system is reduced, and the liver gradually returns to its original state due to its blood-storing function. The gallbladder does not change much and the portal diameter decreases. This study can lay a foundation for the future research on the hepatobiliary portal vein system, and it is expected to provide a safe, non-invasive, reliable, and new indicator for the medical supervision of sports medicine.

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