To investigate the effect of high-intensity exhaustive exercise on body and the molecular mechanism of oxidative stress regulating apoptosis of cardiovascular endothelial cells (CVECs), 70 college students who took an aerobics course were recruited as the research subjects, all of which were divided into the high-intensity group (35 students) and the moderate-intensity group (35 students). The Internet of Things- (IoT-) based human exercise information monitoring system was employed to collect the electrocardiogram, serum indexes, and oxidative stress indexes of the two groups of subjects after exercise. Moreover, 30 clean male SD rats were divided into exhaustive exercise group (n = 10), routine exercise group (n = 10), and blank control group (n = 10) using treadmill exercise as stress source, and various physiological indexes of the three groups were compared. In human experiments, the time-domain indexes of heart rate variability (HRV), 50 ms in the total number of sinus heartbeats (PNN50), the standard deviation of all NN intervals (SDNN), standard deviation of mean NN interval (SDANN), standard deviation of difference between adjacent NN intervals (SDSD), root mean square (RMSSD) in the high intensity group were lower than those in the moderate intensity group (P < 0.05). The levels of T-sensitive troponin I (Tnl-ultra), cortisol (COR), high-sensitive troponin T (TnT-hs), high-sensitive C-reactive protein (hs-CRP), and human heart-type fatty acid binding protein (HUMAN H-FABP) in high intensity group were higher than those in moderate intensity group (P < 0.05).

Experiments on animals found that SOD content and mRNA expression of fork-head box 03A (FOX03A) and silencing-information regulator 1 (Sirt1) in serum of rats in exhaustion exercise group were lower than those in the routine exercise group and blank control group, while lactate dehydrogenase (LDH) and malondialdehyde (MDA) contents were opposite (P < 0.05). In short, strenuous exercise made the body in the state of acute stress, leading to the disturbance of cardiac autonomic nervous function and sympathetic nervous function, and increasing the risk of malignant arrhythmia. Oxidative stress induced by exhaustive exercise may promote the apoptosis of CVECs by reducing the expression of Sirt1 and FOX03A and locating FOX03A to the nucleus.

1. Introduction

With the rapid development of social economy, people pay more and more attention to their own health, and it has become a recognized way to improve their physical fitness through some physical exercises [1–3]. Exercise has obvious benefits. It can regulate the metabolism of the body to some extent, improve cardiopulmonary function, build a good body shape, and even strengthen the nervous system function [4]. In the actual exercise, however, it is necessary to choose the intensity of exercise reasonably. Exercise intensity is roughly graded into low intensity, moderate intensity, and high intensity. In general, calories consumed during moderate-intensity activity are approximately 3–6 times compared to sedentary activity, and 6 times or more during high-intensity activity [5, 6]. Studies showed that the human
body’s demand for oxygen increases greatly during exercise, and the normal oxygen supply cannot meet the current demand. At that time, the reactive oxygen species generated in the body will exceed the current scavenging capacity of the body, resulting in oxidative stress reaction [7]. Appropriate oxidative stress can improve the antioxidant capacity of the human body, which is not only harmless but beneficial to the body, and has an important significance of defense compensation. However, excessive oxidative stress exceeds the normal antioxidant capacity of the human body and causes obvious damage to the body [8, 9]. Therefore, it is necessary to find the exercise intensity suitable for ourselves and realize reasonable fitness.

With the discovery of computer information technology and artificial intelligence, Internet of Things (IoT) has become another change in the information age after computer and Internet. It can be applied to the fusion of network and object through intelligent perception, recognition technology, ubiquitous computing, and other communication perception technologies [10–12]. At present, IoT has been widely used in smart industry, smart agriculture, smart city, and smart medical, with very bright prospects. IoT has been applied to human movement monitoring for a long time. From the initial manual acquisition to the real-time intelligent acquisition by wireless network and computer server, the monitoring level is getting higher and higher [13, 14]. Masuki et al. [15] developed a device equipped with a triaxial accelerometer and barometer to measure energy expenditure during interval walking training with a slope. Leveraging an IoT system that enables users to receive instructions from trainers based on their walking records has low cost and requires few personnel and has value in clinical medicine. At the same time, the current monitoring equipment is also changing from large instruments to small wearable devices. Wearable devices have many advantages, such as portability, long-term dynamic monitoring without affecting human activities, and affordable and high popularity [15–17]. The medical field is the field with the most mature development of smart wearable devices and rigid demand. There are many forms of wearable devices, such as thermometers, watches, and exoskeletons, which are often used for health monitoring and auxiliary treatment [18, 19]. The functions of wearable devices are relatively more concentrated in the field of sports, and they generally acquire users’ exercise physiological data, to guide users to exercise more scientifically [20]. Cui et al. [21] combined wearable sensor technology with optimized energy-saving algorithms to build a sports monitoring system to help athletes monitor their own health during physical exercise. It was found that the proposed monitoring system achieved 97.8% high accuracy ratio, 95.3% performance ratio, 9.4% energy consumption, 13.1% latency, and 98.2% average running time compared with existing methods. Giving the significant changes in heart rate, body temperature, oxygen saturation, pulse, and other physiological parameters during physical exercise, a human movement information monitoring system was designed based on physiological parameters such as heart rate, blood, and oxygen with the help of computer IoT.

To sum up, the application of IoT to human movement research is a hot topic at present. However, the underlying mechanism of high-intensity exercise-induced oxidative stress is less explored. Therefore, seventy college students who took the aerobics course were recruited as the research objects and were divided into high intensity group (n = 35) and moderate intensity group (n = 35). The IoT-based human exercise information monitoring system was used to collect the electrocardiogram, serum indexes, and oxidative stress indexes of the two groups of subjects after exercise. With treadmill exercise as a stressor, thirty clean grade male SD rats were divided into exhaustive exercise group (n = 10), routine exercise group (n = 10), and blank control group (n = 10). Various physiological indexes of rats in the three groups were compared to comprehensively evaluate the effects of exhaustive exercise on the body and the molecular mechanism of oxidative stress regulating cardiovascular endothelial cell (CVEC) apoptosis, in order to provide theoretical support for the monitoring of human physiological data and the prevention of adverse reactions in the state of exhaustive exercise.

2. Materials and Methods

2.1. Research Objects. Seventy college students, 31 males and 39 females, who took the aerobics course in Henan University were selected as the research subjects. All subjects volunteered to participate and signed informed consent prior to the implementation of the project. Members of the research group were responsible for publicizing the main content, purpose, and significance of the research. All subjects passed the physical examination.

Inclusion criteria were as follows: (i) no disease history; (ii) no obvious physical defects; (iii) those who had not experienced high-intensity exercise within seven days; (iv) no joint injury; (v) those who did not drink alcohol or stimulant beverage within ten hours before the experiment; and (vi) aged over 18 years old.

Exclusion criteria were as follows: (i) those whom with cardiovascular disease; (ii) those whom with pulmonary diseases; (iii) the existence of mental diseases; (iv) those who had performed manual operations within three months; and (v) smokers and alcoholics.

2.2. Experiment Groups and Test Procedures. All subjects were divided into high intensity group (n = 35) and moderate intensity group (n = 35) by random number table method.

Test environment was illustrated in Figure 1. To avoid interference from external factors, a rectangular area of 4 × 7 meters was selected as the test site, and subjects had enough space for exercise. The front of the subject was a large screen (playing aerobics video), and the rear was the staff for basic data monitoring and collection. All devices in the space remained unchanged during the process.

The test process was shown in Figure 2. Before the experiment, the height, weight, body fat, and other basic information of subjects were collected by body fat composition testing instrument (InBody Co., Ltd. (Shanghai)) and
portable height and weight measuring instrument (Zhengzhou Shanghe Electronic Technology Co., LTD.). Before the test, the subjects should learn half an hour in advance to get familiar with the whole set of movements of calisthenics, to avoid the inadaptability of the subjects to the movement rhythm in the later experiment.

After the subjects’ mental state was stable, they should wear the human movement monitoring system based on the data collection of heart rate and blood oxygen saturation. Then, the subjects followed the high-intensity calisthenics video for ten minutes of fitness exercise, after which, the exercise equipment and exercise monitoring system were removed for relaxation activities.

As for high-intensity complex calisthenics, the high-intensity full-body fat burning calisthenics from Keep was selected, which lasts for 15 minutes. They include jumping jacks in place, prisoner squats, fast high leg lifts, standing elbow-to-knee, mountain climbers, and lunges, involving the upper limbs, lower limbs, trunk, head, neck, feet, hips, and other body parts, which was very comprehensive. During the process, the Polar heart rate remote control was used to determine that subjects achieved high intensity exercise.

Moderate intensity calisthenics adopted the college routine calisthenics, which lasts for 10 minutes, including jump, jumping jacks, lunge jump, step, back kick jump, bounce kick jump, and kick jump, involving the upper limbs, lower limbs, trunk, head, neck, feet, and hips. During the process, Polar heart rate remote control device was used to confirm that subjects had achieved moderate intensity exercise, and the heart rate should be controlled at about 130 times/min.

2.3. Threshold Denoising Algorithm. Dual-density wavelet transform denoising algorithm [22] is adopted as an analysis method for electrocardiogram (ECG) data processing. Compared with traditional wavelet changes, dual-density wavelet transform denoising algorithm has one scale function and two wavelet functions, which is expressed by the following equations.

\[ f(i) = \sqrt{2} \cdot \sum_{m} l_0(m)f(2i - m). \]  

\[ a_1(i) = \sqrt{2} \cdot \sum_{m} l_1(m)f(2i - m). \]  

\[ a_2(i) = \sqrt{2} \cdot \sum_{m} l_2(m)f(2i - m). \]  

\[ a_2(i) = a_1 \left( i - \frac{1}{2} \right). \]
In the above equations, \( f(i) \) represents the scale function, \( \alpha_1(i) \) and \( \alpha_2(i) \) are both wavelet functions, equation (4) is the relationship between two wavelet functions, \( m \) is constant, \( l_0 \) represents low-pass filter with symmetric impulse response, and \( l_1 \) and \( l_2 \) are both high-pass filters with antisymmetric impulse response. The relationship between a low-pass filter and two high-pass filters is expressed as follows.

\[
l_0(u) = l_0(u) + l_1(u)l_1
dd{u} = -l_2(u)l_2
dd{u}.
\]  

\( (5) \)

Then, soft threshold function [23] is introduced as a function processing method, which is expressed as follows.

\[
\kappa = \begin{cases} 
\text{sgn}(c) \left| |c| - \tau \right| & |c| \geq \tau \\
0 & |c| < \tau
\end{cases}
\]

where \( \kappa \) represents the wavelet coefficient after threshold processing, \( \tau \) represents the threshold, and \( c \) represents the wavelet coefficient before processing.

The selection of threshold has a great influence on the effect of information denoising. The heuristic threshold method [24] was adopted to select the threshold. When the SNR is low, the fixed threshold is selected, and \( \tau = \delta \sqrt{2 \log eK} \). When the SNR is high, stein’s unbiased likelihood estimation threshold is selected, and \( \tau = \delta \sqrt{RIG_{\min}} \). \( K \) represents signal size, \( \delta \) is the noise variance, and \( RIG_{\min} \) is the minimum likelihood estimation threshold.

2.4. IoT-Based Human Movement Information Monitoring System. The human movement information monitoring system proposed in this work (Figure 3) mainly includes data collection (human physiological information data), data wireless transmission (Bluetooth, repeater, and wireless network), data processing (mathematical algorithm), and data display (computer, tablet, and mobile device). The overall design concept is as follows: (i) it is as small as possible to reduce the discomfort of wearing subjects; (ii) it can identify the state of human movement; (iii) it can reduce system power consumption and can work continuously for more than 1 day; and (iv) the operation method of equipment is very simple.

The data collection part (Figure 4) mainly includes power supply, physiological information collection module, IIC protocol sensor, and Bluetooth. Physiological information acquisition module is used to collect various physiological information change data in human exercise, including heart rate, electrocardiogram, and blood oxygen. The data obtained by IIC sensor is transmitted to the relay station through Bluetooth.

The Bluetooth module adopts the main control chip CCM3310S, which can be used as the core computing and processing device of Bluetooth products, and has excellent power consumption, transmission, and receiving performance. Bluetooth antenna uses steel antenna, which is suitable for almost all small electronic products. It can do
complex antenna of more than 10 frequency bands, such as 4G, with good performance and low cost. In circuit design, 40 MHz crystal oscillator is used to provide high frequency clock, and 27 MHz crystal oscillator is used to provide low frequency clock.

The data transmission part mainly includes communication module connecting front-end sensor data, cloud platform communication module, and main control system module (Figure 5). The core of the control system uses PLC programming, and the communication module connecting the front-end sensor data uses RS485 communication.

2.5. Observation Indexes. 10 mL elbow venous blood of the subjects was collected on an empty stomach at 8 am and
added into 4 mL procoagulant tube containing inert separation gel, centrifuged at 3,500 rpm at 4°C for 20 min. Precipitation was discarded, and supernatant was collected. Hypersensitive troponin I (TnI-Ultra), cortisol (COR), hypersensitive troponin T (TnT-hs), hypersensitive C-reactive protein (hs-CRP), and human heart-type fatty acid binding protein (HUMAN H-FABP) were detected.

ECG was recorded and time domain indexes of heart rate variability were calculated, including the percentage of the difference between adjacent NN intervals greater than
Figure 8: Evaluation results of human motion state by the system. (1-12 represents 12 subjects). (a) walk; (b) go up and down the stairs; (c) run; and (d) squats.
50 ms in the total number of sinus heartbeats (PNN50), the standard deviation of all NN intervals (SDNN), standard deviation of mean NN interval (SDANN), standard deviation of difference between adjacent NN intervals (SDSD), root mean square (RMSSD) of the difference between adjacent NN intervals, and the number of NN intervals divided by the height of the histogram of NN intervals (HRV trigonometric exponent).

2.6. Experiments on Animals

(i) Experimental animals and grouping: 30 clean grade male Sprague-Dawley (SD) rats, weighing 100-120 g, were selected from Henan University Animal Experimental Center. The included rats were fed normally in the animal room for two weeks to adapt to the new environment. These rats were divided...
Figure 10: Continued.
into exhaustive exercise group (n = 10), routine exercise group (n = 10), and blank control group (n = 10) by random number table method. This animal experiment followed the principle of Reduction, Replacement, and Refinement, and was approved by the Animal Experiment Ethics Committee of the University.

(ii) Exercise program: rats in the exhaustive exercise group were trained with high intensity for two weeks. Training procedures: (i) slope 5 degrees, 15 m/min, 15 minutes; (ii) slope 10 degrees, 15 m/min, 15 minutes; and (iii) slope 15 degrees, 20 m/min, 20 minutes. Exhaustion was determined when the rats stayed at the 1/3 place for more than 4 times and were unable to recover their motor ability after stopping. The routine exercise group also carried out platform exercise, and the training program was slope 0 degrees, 5 m/min, 15 minutes, no exercise in the rest of the time. The rats in the blank control group did not exercise but were put on the treadmill at the same time with the other two groups.

(iii) Sample treatment: after exercise, the rats in the three groups were anesthetized with ether, and 3 mL of inner canthal blood was taken and placed into a centrifuge tube with heparin sodium. Then, the rat chest was cut open, and the heart tissue was removed and stored in 4% paraformaldehyde solution.

(iv) Serum biochemical indexes including lactate dehydrogenase (LDH) activity, nitric oxide (NO) level, malondialdehyde (MDA) level, and superoxide dismutase (SOD) activity in serum of rats were determined. Myocardial tissue samples were stained with Hematoxylin eosin (HE), and the morphological changes of myocardial tissue were observed with light microscope. RNA expression: the mRNA expressions of protein kinase B(AKT), transcription factor FOX03A (FOX03A), and silencing message regulator 1 (Sirtl) were detected by q RT-PCR.

2.7. Statistical Methods. SPSS 22.0 was used for data processing. Mean ± standard deviation was used for measurement.
data, and percentage (%) was used for counting data. Pairwise comparison was performed by one-way ANOVA. The difference was statistically significant at $P < 0.05$.

3. Results

3.1. Performance Analysis of Human Motion Monitoring Equipment. Firstly, Bluetooth transmission distance and packet loss rate were calculated to evaluate the data transmission capability of the system. The test environment was outdoor common environment, and the transmission distance was set as 3, 5, 7, 9, 11, 13, 15, 17, and 19 meters. Each packet was 25 bytes, and two packets were sent every 10 seconds for a total of 1,500 packets. The test results were shown in Figure 6. Within the transmission distance of 11 meters, the system received 1,500 packets with a packet loss rate of 0. At 11 meters, the packet loss rate increased gradually as the transmission distance increased.

In terms of the reliability of obtaining physiological information data (heart rate and blood oxygen saturation were taken as analysis indexes), 12 college students were selected from the subjects, including 6 males and 6 females. The heart rate and oxygen saturation of 12 subjects were measured simultaneously with the PHILIPS finger clip pulse oximeter and the wearable device in this research. Three sets of data were collected from each subject, and the two results were compared. Figure 7 showed that the heart rate and blood oxygen saturation data of 12 subjects collected by this device were similar to those obtained by PHILIPS finger clip pulse oximeter, and the difference between them was not substantial ($P > 0.05$).

To further analyze whether the equipment was suitable for high-intensity exercise evaluation, 12 college students...
were asked to do squatting, running, and walking up and down stairs, 60 times each. Three sets of data were collected from each subject and averaged. Then, the correct judgment times were recorded, and the misjudgment rate was calculated. The results were shown in Figure 8. The evaluation error rate of running for the 12 subjects was within 2.5, and the evaluation error rate of walking up and down stairs was between 5 and 8.5%. The assessment error rate for running ranged from 10 to 15%, and for squatting from 14 to 17%.

3.2. Basic Information of Subjects. Figure 9 shows that there was no statistical significance in age, height, weight, grade distribution (freshman, sophomore, and junior), major type (science, arts, and art), and other information of subjects in the high intensity group and the moderate intensity group \((P > 0.05)\).

3.3. ECG Results of Subjects in the High and Moderate Intensity Groups. In Figure 10, the maximum heart rate, average heart rate, total heart rate, sinus tachycardia, sinus bradycardia, 24-h sinus tachycardia rate, 24-h sinus bradycardia rate, rate of sinus arrhythmia, number of atrial premature beats, number of ventricular premature beats, complete right bundle branch block, and intermittent second-degree type 1 atrioventricular block of subjects in high intensity group were remarkably superior to those in moderate intensity group, and the difference was substantial \((P < 0.05)\). The minimum heart rate of subjects in high intensity group was notably inferior to that in medium intensity group, and the difference was substantial \((P < 0.05)\). There were no considerable differences in atrial premature beats, atrial tachycardia, ventricular premature beats, and ventricular tachycardia between subjects in the high intensity group and those in the moderate intensity group \((P > 0.05)\).

3.4. ECG Manifestations of Different Arrhythmias in Subjects. Figure 11 shows that subjects in the high intensity group had more types of ECG with different arrhythmias, including sinus bradycardia with arrhythmia, sinus tachycardia, intermittent second-degree type 1 atrioventricular block, early repolarization with ventricular premature beats, and atrial premature beats with nonspecific ST-T changes.

3.5. Comparison of Temporal Index of Heart Rate Variability between Subjects of High Intensity Group and Moderate Intensity Group. In Figure 12, the time-domain indexes of heart rate variability SDNN, SDANN, SDSD, PNN50, RMSSD, and HRV triangle index of subjects in the high

![Figure 12: Comparison of time domain indexes of HEART rate variability between the high intensity group and the moderate intensity group. Note: (a) is SDNN, SDANN, and SDSD; (b) is the trigonometric index of PNN50, RMSSD, and HRV. *was substantial difference compared with the high intensity group \((P < 0.05)\).]
intensity group were notably inferior to those in the moderate intensity group \((P < 0.05)\).

3.6. Comparison of Serum Parameters between High Intensity Group and Moderate Intensity Group. In Figure 13, the TnI-Ult, TnT-hs, and HUMAN H-FABP of subjects in the high intensity group were remarkably superior to those in the moderate intensity group \((P < 0.05)\).

In Figure 14, the stress indexes COR and hs-CRP of subjects in the high intensity group were remarkably superior to those in the moderate intensity group \((P < 0.05)\).

3.7. Comparison of Serum Indexes among Three Groups. Figure 15 shows that the contents of NO and SOD in serum of rats in exhaustive exercise group were notably inferior to those in routine exercise group and blank control group.
Serum LDH and MDA in exhaustive exercise group were remarkably superior to those in routine exercise group and blank control group \((P < 0.05)\).

3.8. HE Staining Results. Figure 16 shows the HE staining results of myocardial tissue of rats in the three groups. The myocardial cells in the blank control group were cylindrical, with uniform cytoplasm staining, clear cell boundaries, and orderly arrangement of myocardial fibers. There were obvious pathological changes in cardiovascular tissues in the exhaustive exercise group, such as cytoplasmic dissolution of myocardial cells, blurred cell boundaries, incomplete nucleus structure, myocardial fiber fracture, and inflammatory cell infiltration. There were also some pathological changes in cardiovascular tissues in the routine exercise group, but the overall degree was relatively mild, with a small amount of myocardial fiber swelling and fracture.

3.9. mRNA Expression of AKT, Sirtl, and FOX03A in Three Groups. Figure 17 shows that the levels of Sirtl and FOX03A mRNA expression in the exhaustive exercise group were notably inferior to those in the routine exercise group and the blank control group \((P < 0.05)\). The expression level of AKT mRNA in the exhaustive exercise group was not greatly different from that in the routine exercise group and the blank control group \((P > 0.05)\). Figure 18 shows the AKT, Sirtl, and FOX03A PCR bands of rats in the exhaustive exercise group, routine exercise group, and blank control group, with DNA Marker as a control.

4. Discussion

Clinical studies showed that exhaustive exercise such as long-term overload exercise or super physical labor causes damage to the cardiovascular system and causes the occurrence of cardiovascular diseases, in which CVEC damage is the key factor. Therefore, it is necessary to deeply analyze the internal regulation mechanism of exhaustive exercise on CVEC apoptosis \([25–27]\). Firstly, a human movement information monitoring system based on IoT was
constructed, and its performance was analyzed. It was found that within the transmission distance of 11 meters, the system received 1,500 packets with a packet loss rate of 0. At 11 meters, the packet loss rate increased gradually as the transmission distance increased. Generally, the distance of indoor monitoring of human physiological information is not more than 10 meters, and this system meets the research requirements [28]. To further analyze whether the equipment was suitable for high-intensity exercise evaluation, the misjudgment rate of 12 college students doing squatting, running, up and down stairs, and walking by the system was analyzed. The evaluation error rate of the 12 subjects’ running was within 2.5%, the evaluation error rate of walking up and down stairs was between 5 and 8.5%, and the evaluation error rate of running was between 10 and 15%. The assessment error rate of squatting was between 14 and 17%, which indicated that the system had a small assessment error rate of strenuous exercise and had great application value [29].

Seventy college students who took the aerobics course were selected as the research object and were divided into high intensity group \( (n = 35) \) and moderate intensity group \( (n = 35) \). The proposed system was used to collect physiological data of subjects during exercise, and the ECG and stress indexes of the two groups were compared. The ratio of sinus arrhythmia, number of premature atrial beats, number of premature ventricular beats, complete right bundle branch block, intermittent second type 1 atrioventricular block, nonspecific ST-T changes, and early repolarization of subjects in the high intensity group were remarkably superior to those in the moderate intensity group. The time-domain indexes of HEART rate variability (HRV), SDNN, SDANN, SDSD, PNN50, RMSSD, and HRV were notably inferior to those in the moderate intensity group \( (P < 0.05) \). The HRV

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![HE staining of myocardial tissue in three groups of rats (400x).](image1)

**Figure 16:** HE staining of myocardial tissue in three groups of rats (400x). Note: (a) is the blank control group; (b) is the routine exercise group; and (c) and (d) are the exhaustive exercise groups.

![AKT, Sirtl, and FOX03A mRNA expression in the three groups of rats.](image2)

**Figure 17:** AKT, Sirtl, and FOX03A mRNA expression in the three groups of rats. Note: * meant that the difference was considerable compared with the exhaustive exercise group \( (P < 0.05) \).
is a phenomenon of periodic changes of sinus rhythm within a certain period, namely, slight differences in successive interatrial intervals, and is an important index of sympathetic and parasympathetic nerve activity in the autonomic nervous system. Schneider et al. [30] studied 37 well-trained athletes who underwent daily upright tests during a 6-day overload cycle and a 4-day recovery period. After strength training overload, supine heart rate and vagus HRV significantly increased and decreased, respectively (small effect), and standing records remained unchanged. Conversely, high-intensity interval training overload resulted in a decrease in heart rate and an increase in vagus HRV (small effect), while supine records remained unchanged [30]. The results indicated that high-intensity exercise can lead to the disorder of cardiac autonomic nerve function and the imbalance of sympathetic nerve function. It can also increase the risk of premature ventricular beats, sinus arrhythmia, complete right bundle branch block, intermittent second-degree type 1 atroventricular block, and other malignant arrhythmias. In addition, the TnI-Ult, TnI-hs, HUMAN H-FABP, COR, and hs-CRP of subjects in high intensity group were remarkably superior to those in moderate intensity group (P < 0.05). This is similar to the conclusion proposed by DeBlauw et al. [31] that HRV-guided high-intensity interval training produced similar changes in cardiovascular function, body composition, and physical fitness as scheduled high-intensity functional training. This indicates that the body is in a state of acute stress caused by exhaustive exercise, accompanied by myocardial damage. The reason may be that high-intensity exercise causes skeletal muscle damage, activates the acute immune response, and triggers inflammation.

To better understand the molecular mechanism of oxidative stress and CVEC apoptosis induced by exhaustive exercise, animal experiments were conducted. Thirty clean grade male SD rats were divided into exhaustive exercise group (n = 10), routine exercise group (n = 10), and blank control group (n = 10). The results showed that the contents of NO and SOD in serum of rats in exhaustive exercise group were notably inferior to those in the routine exercise group and blank control group. The contents of LDH and MDA were remarkably superior to those of the routine exercise group and the blank control group (P < 0.05), suggesting that exhaustive exercise can cause the increase of free oxygen and thus oxidative stress [32]. HE staining results showed that there were obvious pathological changes in the cardiovascular tissues of the rats in the exhaustive exercise group, such as cytoplasmic lysis of myocardial cells, blurred cell boundaries, incomplete nucleus structure, myocardial fiber fracture, and inflammatory cell infiltration. The mRNA expression levels of Sirtr1 and FOX03A in exhaustive exercise group were notably inferior to those in the routine exercise group.

Figure 18: AKT, Sirtr1, and FOX03A PCR bands in the three groups of rats (1-3 are exhaustive exercise group, routine exercise group, and white control group.). Note: (a) is the AKT; (b) is Sirtr1; and (c) is FOX03A.
group and blank control group ($P < 0.05$). FOXOs is a key regulator of various cell processes, apoptosis, cell cycle progression, and oxidative stress resistance [33]. These results suggested that oxidative stress induced by exhaustive exercise may promote the apoptosis of CVECs by reducing the expression of Sirt1 and FOXO3A and locating FOXO3A to the nucleus.

5. Conclusion

Seventy college students who took the aerobics course were selected as the research object and were divided into high intensity group ($n = 35$) and moderate intensity group ($n = 35$). The IoT-based human exercise information monitoring system was used to collect the electrocardiogram, serum indexes, and oxidative stress indexes of the two groups of subjects after exercise. With treadmill exercise as a stressor, 30 clean grade male SD rats were divided into exhaustive exercise group ($n = 10$), routine exercise group ($n = 10$), and blank control group ($n = 10$). The contents of LDH, NO, MDA, and SOD and HE staining of myocardial tissue and miRNA expression levels of AKT, FOXO3A, Sirt1, Bax, and BD-XL were compared among the three groups. It was found that high-intensity exhaustive exercise makes the body in a state of acute stress, leading to disturbances of cardiac autonomic nerve function and sympathetic nerve function, and increasing the risk of malignant arrhythmia. Oxidative stress induced by exhaustive exercise may promote the apoptosis of CVECs by reducing the expression of Sirt1 and FOXO3A and locating FOXO3A to the nucleus. However, the subjects only carried out high-intensity body building exercises, and the training method was relatively single, which could not fully reflect all the characteristics of complex exercises. In addition, the subjects’ samples are all ordinary college students in school, which is not universal. Later, different types of subjects’ samples will be included, and other types of high and light exercise will be added to make the research results more universal. In conclusion, this work provides data reference for clinical research on oxidative stress regulation of CVEC apoptosis induced by exhaustive exercise.

Data Availability

The all research data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares that he/she has no conflicts of interest.

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