Remote Monitoring Method of Athlete Training Intensity Based on Mobile Internet of Things

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Abstract. In order to better design the athlete training scheme, a remote monitoring method of athlete training intensity based on mobile Internet of things is proposed. Combined with a certain logistics network to collect athletes' training body data, build athletes' training body data monitoring and management system, and simplify the steps of athletes' training intensity monitoring and management. Finally, the experiment proves that the remote monitoring method of athletes' training intensity based on mobile Internet of things has high practicability in the process of practical application and fully meets the research requirements.

Keywords: Mobile Internet of things · Athletes · Training monitoring

1 Introduction

The emergence of remote monitoring of athletes' training intensity in the field of competitive training, fitness and rehabilitation mainly stems from the short-term and efficient training effect. This training method has been used in sports monitoring since the 1970s. For example, various versions have appeared in the preparation of football events. At present, the remote monitoring of athletes' training intensity is not only frequently used in the preparation of athletes and sports teams, but also highly sought after in the field of fitness, according to the annual survey of the American Academy of sports medicine. At present, there is a strong interest in the research of remote monitoring of athletes' training intensity in the field of scientific research, including a large number of exploratory research on remote monitoring of athletes' training intensity by scientific researchers in the fields of sports science and sports medicine [1]. The difficulty in the application of remote monitoring of athletes' training intensity lies in how to make a reasonable training plan to achieve the predetermined training objectives. Different variables involved in controlling the training intensity will lead to different metabolism and muscle nerve reactions, resulting in different training effects. There are many variables involved in the remote monitoring of athletes' training intensity, and the combination forms of variables are diverse. Arbitrarily adjusting one of the many variables will lead to the difference of training effects.

W. Fu and L. Yun (Eds.): ADHIP 2022, LNICST 468, pp. 366–380, 2023.
https://doi.org/10.1007/978-3-031-28787-9_28

This paper proposes a remote monitoring method of athletes' training intensity based on mobile Internet of things. On the basis of the athlete's training body data collection, it is processed. Monitor the intensity of sports training based on mobile Internet of things terminals.

2 Remote Monitoring of Athletes' Training Intensity

2.1 Athlete Training Body Data Collection

Athletes' training body data collection is the core function of the whole, and the accuracy and reliability of sports monitoring algorithm also determine the performance of the system. According to the collected data in multiple scenes, after comprehensive comparative analysis, an algorithm for motion monitoring is designed. Firstly, the sensor transmits the generated signal to MCU for preprocessing. The preprocessing link includes signal superposition, digital filtering and other links, of which the digital filtering link is the key. The effect of digital filtering will directly affect the selection of characteristic parameters, and then affect the accuracy of final state recognition. Then, the motion eigenvalues are extracted as input parameters to judge the motion state and step recognition, and the conditional transformation of motion state is realized by using state machine [2]. Motion state recognition essentially realizes the function of classifier, which classifies the motion eigenvalues corresponding to different motion states. At the same time, the motion eigenvalues that have been judged will also be input into the classifier as training data to continuously optimize the parameters of the classifier, improve the performance of the monitoring algorithm and realize the intellectualization of the algorithm [3]. However, in the case of limited existing hardware resources, it is difficult to implement the multi classifier algorithm at the bottom, so the processing method of multi conditional judgment is used for programming. After making the motion state discrimination, enter the state discrimination subroutine to make a more specific and in-depth discrimination of each state. Based on this, optimize the process structure of athletes' training body data acquisition, as shown in Fig. 1:

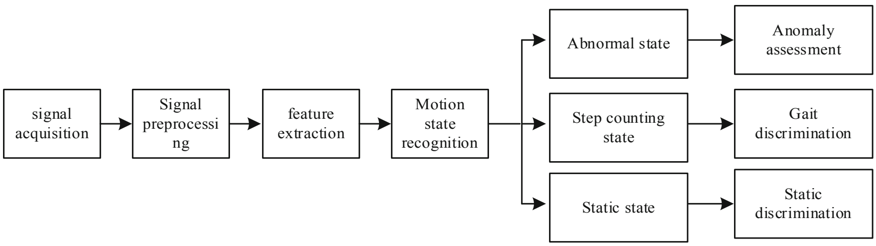

Fig. 1. Structure diagram of athlete training body data acquisition

In the case of movement, the movement of the trunk is mainly forward, backward and vertical. Human walking can be approximately regarded as periodic motion. Here, we can choose to take each step as a cycle or two consecutive steps as a cycle for analysis

[4]. In this paper, we choose one step as a cycle, starting with the heel of the moving foot off the ground and ending with the landing of the moving foot into a supporting foot. During the movement, the foot goes through the process of stepping, landing and supporting. In this process, the vertical acceleration is generated by the combined force of the reaction force of the ground to the foot and gravity, and the forward and backward acceleration is generated by the friction between the ground and the foot. The changes of vertical and forward acceleration are shown in Table 1:

Table 1. Changes of trunk motion acceleration

Trunk movement	Pedal	Stride forward	Landing	Brace
Vertical direction	Decrease → increase	Enlarge	Increase → decrease	Reduce
Fore-and-aft direction	Enlarge	Increase → decrease	Reduce	Decrease → increase

In the process of human swing arm walking, the motion of the upper limb is similar to periodic motion. Assuming that the arm does not exert force in the swing process and does not consider the friction resistance, the model can be simplified as a simple harmonic pendulum, and the acceleration of the sensing equipment can be decomposed into tangential component and normal component [5]. From one deflection angle maximum position to another deflection angle maximum position θ to m or g to e, the tangential acceleration φ decreases first and then increases, and the normal acceleration l increases first and then decreases. The following equation can be obtained from the law of conservation of energy and Newton's law of mechanics:

$$a_t = mge \sin\theta \tag{1}$$

$$\frac{1}{2}a_c^2 = mgl(\cos\theta - \cos\varphi) \tag{2}$$

Thus, the acceleration of any point (e.g. point B) is:

$$\lambda = g\sqrt{a_c^2 \sin^2\theta - \cos\varphi\cos\theta + a_t^2 \sin^2\varphi} \tag{3}$$

When you know the amplitude of a person's swing arm when walking φ (i.e. the maximum deflection angle between arm and trunk), the change process of resultant acceleration can be calculated. Assuming point B and point D are equilibrium points, the ideal change of acceleration in a swing arm cycle is shown in Table 2:

Table 2. Variation of upper limb swing acceleration

Arms swing	A → B	B → C	C → D	D → E
Tangential at	Reduce		Enlarge	
Normal ac	Enlarge		Reduce	
Closing acceleration a	Reduce	Enlarge	Reduce	Enlarge

To understand the concept of exercise load, you can't take it for granted. After reading a lot of research on sports load, due to different starting points and professional backgrounds, the description of the basic concept of sports load is also very different. In this paper, there are a lot of fuzziness and contradictions in the understanding of the basic concept of sports load, which shows the complexity of sports load itself. In the design process of heart rate monitoring, the author uses heart rate monitoring to reflect the exercise load, and also uses the heart rate area in the application part of exercise heart rate monitoring, and the root of these designs is exercise load. Therefore, how to make a scientific explanation and definition of exercise load has become an urgent task in the theoretical support of this paper, If sports training ignores the internal functional state of the body, excessive or insufficient exercise, then external training will not achieve the desired effect, and even have a negative impact on the physical health of athletes [6]. In order to better study and control the adaptation process of exercise training intensity and body function, the concept of exercise load is introduced. The concept of sports load is based on the mutual adaptation of sports forms and physical function changes. The fundamental purpose of monitoring and adjusting sports load is to scientifically and effectively organize and adjust the factors related to the mutual adaptation of physical function and sports behavior, so as to improve the effectiveness, pertinence and safety of training. The focus of exercise load is the change of body state caused by exercise behavior and the stress response of the body to the process of exercise training.

2.2 Athlete Training Status Monitoring Data Processing

In order to clarify the relationship between various motion states and state transition conditions, this paper uses the nested state machine model to describe each state and its state transition. Because there are many subdivided States, it is difficult to avoid the disorder of logical relationship by using the same state machine, so the classification method is adopted [7]. In terms of structure, the motion state is divided into three parent states: static state, walking state and abnormal state, and the states with similar logical relationship or similar transition conditions are classified into the parent state. Each parent state can be regarded as a separate sub state machine. The monitored states are reasonably organized in the form of nested state machines to form a clearly descriptive motion monitoring state machine model, as shown in Fig. 2:

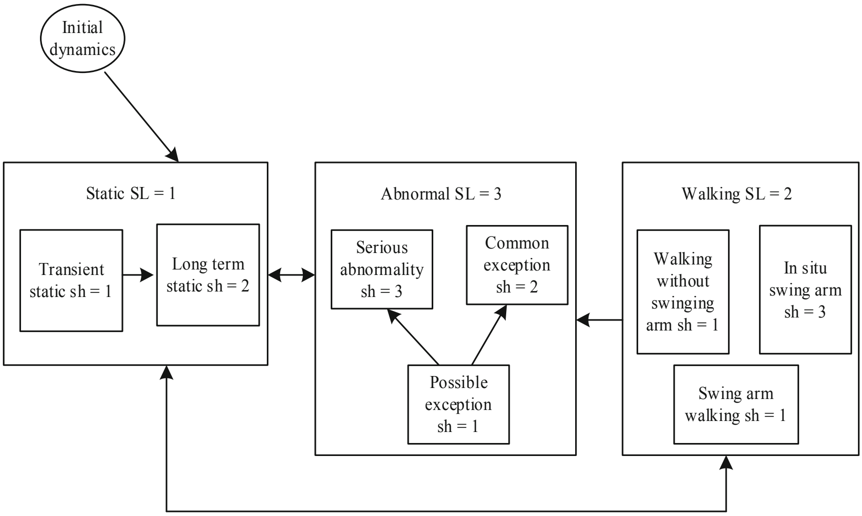

Fig. 2. Athlete training state monitoring data processing model

Among them, the purpose of exercise heart rate monitoring is to help athletes monitor their exercise status in real time and for a long time, and adjust the exercise load in time according to the exercise heart rate, so as to avoid sports injury caused by insufficient exercise intensity and poor exercise effect or excessive exercise, so as to achieve good exercise effect. The basic needs of this paper are: monitoring real-time heart rate, This is the requirement for the sensitivity of heart rate sensor and heart rate acquisition algorithm; It can monitor heart rate for a long time, which is the demand for data storage and analysis of heart rate acquisition equipment and athletes' adherence to heart rate monitoring; It can detect the exercise heart rate, which requires the portability or wearability of the exercise heart rate acquisition device. It can view the exercise heart rate in real time, which is the demand for real-time display of exercise heart rate monitoring; It is the core requirement to adjust the exercise load in time according to the exercise heart rate. This requirement requires us to give a reasonable theoretical model and operable scheme of using exercise heart rate to monitor the exercise load. According to the demand analysis, the functional modules of this are designed as shown in Fig. 3:

When a device is connected, there are only two status roles: master device and slave device. The device that enters the connection state from the initiation state is the master device, and the device that enters the connection state from the broadcast state is the slave device. The master and slave devices communicate with each other and specify the transmission sequence. A slave device can only communicate with one master device, while a master device can communicate with multiple slaves. There may be more than one state machine in the link layer. Of course, there are certain state restrictions when supporting multiple state machines. The multi state combination restrictions of the monitoring link layer are shown in Table 3:

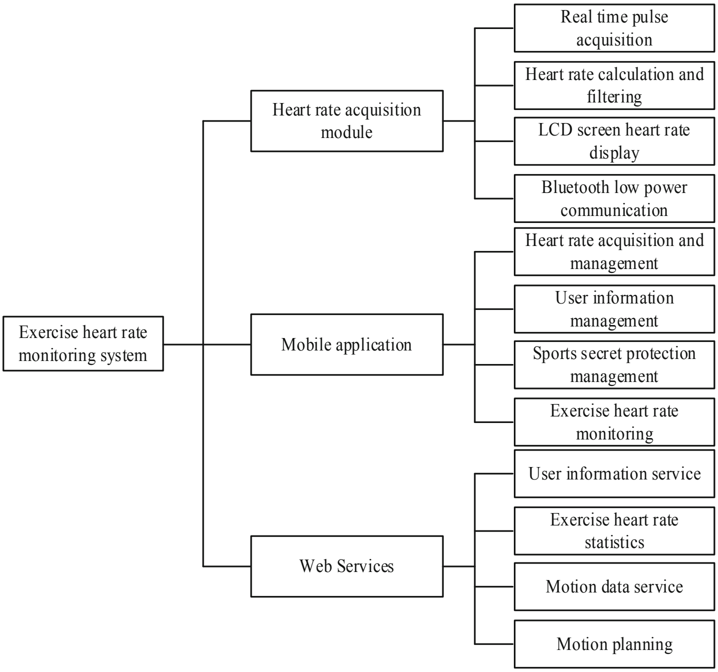

Fig. 3. Functional structure of exercise heart rate monitoring

Table 3. Multi state combination limit of monitoring link layer

Status and roles		Broadcast state	Scanning state	Initiating state	Connected state	
					Main equipment	Slave device
Broadcast state		Prohibit	Allow	Allow	Allow	Allow
Scanning state		Allow	Prohibit	Allow	Allow	Allow
Initiating state		Allow	Allow	Prohibit	Allow	Prohibit
Connected state	Main equipment	Allow	Allow	Allow	Allow	Prohibit
	Slave device	Allow	Allow	Prohibit	Prohibit	Prohibit

Add the motion monitoring program to osal. First, register the task in osal, add the address of the event processing function of the new task to tasks arri, and add the event and event processing function of the new task to the event table and processing function table. Then, add the initialization function of the new task to osallnit tasks, and each task will automatically obtain the assigned task ID. It should be ensured that the sequence of event handlers in the taskbar array corresponds to the order of initialization functions invoked by each task in the salinit Tasks function, so as to ensure that each task's event handler receives the correct task ID. To save the task ID assigned by the osalinittaskso function, to define a global variable for each task to save the event of the motion monitoring service, the corresponding event handler Step Process Evento is invoked. The implementation procedure of the event handler is shown in Fig. 4.

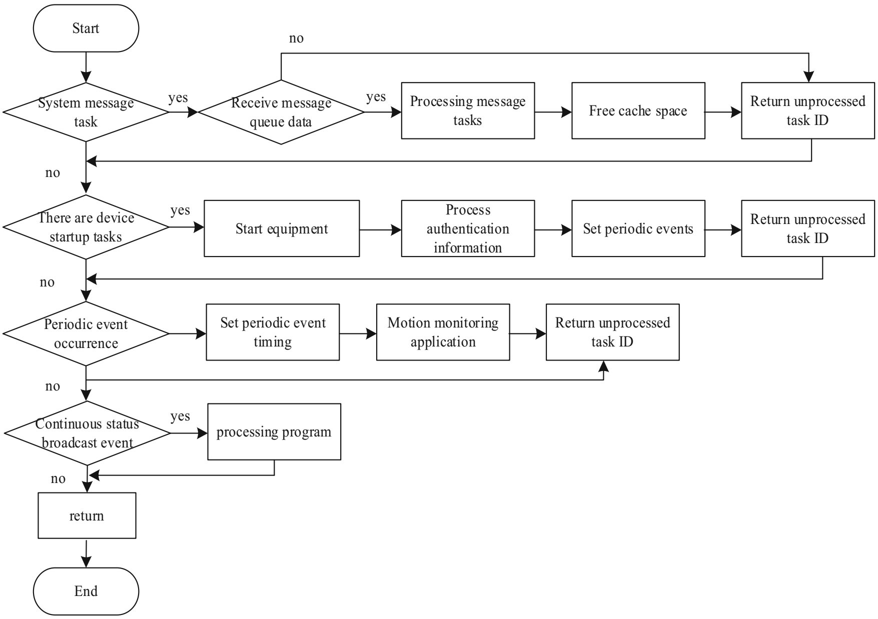

Fig. 4. Flow chart of event handling procedure for sports monitoring

In the process of equipment initialization event processing, the first timing time of periodic event is set, and in the process of periodic event processing, the next timing time is reset. By setting these two parameters, you can adjust the cycle of calling the periodic task processing function, which is the motion monitoring application designed this time. Ideally, regardless of program execution time and other factors, the set values of these two timing times are the cycle of sensor acquisition signal and the cycle of motion monitoring application. In practice, the timing time is less than the sampling period designed by the algorithm.

2.3 Realization of Sports Training Intensity Monitoring

When the human body moves, the values of the three axes of the acceleration sensor represent the sum of the acceleration component and gravity component generated by the human body movement on each axis. The component of gravity direction does not affect the research of this paper. Therefore, the component of vertical direction in this chapter includes gravity component and human acceleration component. Let $a_i(t)$ represent the triaxial acceleration vector of the sensor at time t. in order to calculate the vertical component of the acceleration signal in human motion, first calculate the gravity component when the sensor is stationary, and then use this gravity component and $a_i(n)$ to estimate the actual component in the vertical direction. In order to determine whether the sensor is in a static state, three parameters need to be calculated first, namely, the maximum value and minimum value of the acceleration signal in a sliding window and the average value of each axis:

$$\begin{cases} a_{i\_\max} = \text{Max}(a_i(t))(i = x, y, z, t = 0, 1 \ldots N) \\ a_{i\_\min} = \text{Min}(a_i(n))(i = x, y, z, t = 0, 1 \ldots N) \end{cases} \tag{4}$$

The whole set of motion monitoring sub modules are used to complete the whole set of motion monitoring and real-time control of the whole server. Due to the powerful processing and computing performance of the server, most of the data processing and computing of this system are carried out on the server. The server of motion data real-time monitoring consists of the following six modules: real-time monitoring terminal communication service module, planning task service module, data flow service module, data analysis and processing service module, data base station communication service module and database communication service module. The structure of the server is shown in Fig. 5:

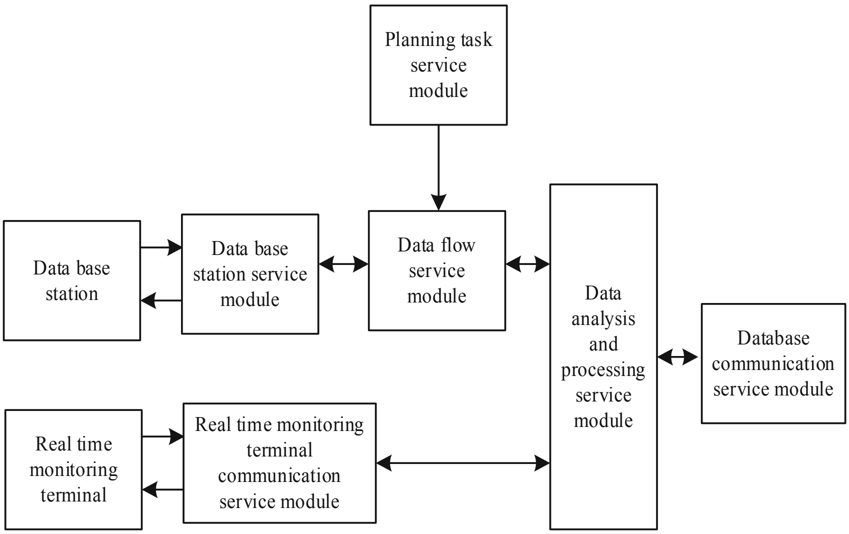

Fig. 5. Structure of motion monitoring server

The real-time monitoring terminal of real-time monitoring of sports data is realized based on Android platform. It is used to present the sports data such as the number of steps and energy consumption generated by the athlete in the process of exercise to the sports observer in real time, so as to grasp the real-time changes of the athlete's physical condition in the process of exercise in time. In order to enable the data acquisition equipment to correctly complete the data communication with the base station, this paper designs a set of data communication protocols to provide guidelines for the data acquisition equipment to send and receive data with the base station. The specific contents of the communication protocols are shown in Table 4:

Table 4. Communication protocol between SCADA equipment and base station

Command name	Command format	Describe
Get the current data of the device	43 44 xx xx	Obtain and set the current data, including device ID, steps, current x, y, z axis acceleration value and remaining power of the device. The first two bytes are the command identification, and the last two bytes represent the current command serial number, which is automatically incremented by PC, the same below
Get movement steps	48 45 xx xx	Obtain the number of operation steps recorded by the equipment, and the equipment will adapt to several data. The return result includes the starting time of network return data, the number of data pieces, and the number of remaining data pieces of the equipment
Set current time	54 55 xx xx	The first two bytes of the current time of calibrating the equipment are the command identification. The last two bytes represent the current instruction sequence number
Set the current exercise index	54 52 xx xx	Set the motion energy consumption data of the current device. The first two bytes are the command identification, and the last two bytes represent the current instruction sequence number
Reset a device	53 54 xx xx	Reset the device and clear the data stored in the device
Address of broadcasting equipment	55 42 xx xx	The device broadcasts its own MAC address to the environment, and adds represents the MAC address of the device

The starting and ending time of sports monitoring is controlled by the sports observer on the real-time monitoring terminal. The monitor can select a specific sports group for monitoring, observe the overall exercise of the class in real time, and also observe the detailed exercise data of specific individuals in the group in real time. Figure 6 describes the workflow of the real-time monitoring terminal:

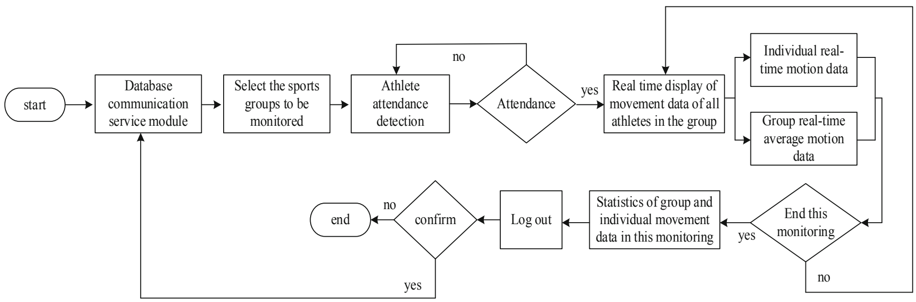

Fig. 6. Work flow chart of real-time monitoring terminal

To sum up, the implementation process of the remote monitoring method of athletes' training intensity based on the mobile Internet of things in this paper is as follows:

Step 1: athlete training body data collection.

Step 2: athlete training status monitoring data processing.

Step 3: perform accurate spatial calculation in common databases.

Step 4: use MBR technology to check the relationship between predicates, eliminate predicate relationships that are inconsistent with the actual situation, and then form a topology data table.

Step 5: calculate the support of the predicate, exclude the items with low support, form the optimal database, and form a new topological relationship data table.

Step 6: complete the training and monitoring according to the topological relationship data table.

3 Analysis of Experimental Results

The proposed method is verified on the intelligent terminal. The intelligent terminal adopts Android operation and is equipped with lis3dh4 acceleration sensor. LIS3DH4 is a three-axis digital acceleration sensor of Italian French semiconductor (st) company. It is packaged in 16 pin plastic, with small and slim overall size and size of only 3mm × 3mm × lmm. It adopts the way of digital output, avoiding the use of other chips for analog-to-digital conversion. The acceleration sensor lis3dh has the acceleration output of x, y and z degrees of freedom, which can sense the motion information of the human body in an all-round way. The measuring range is within ± 2g/ ± 4g/ ± 8g and l6g, and the minimum working current consumption is 2 μA. LIS3DH4 can provide very accurate measurement data output and maintain excellent stability under rated temperature and long-time operation. The sampling rate of the sensor is adjustable between 1-5000Hz. The sampling frequency set in this paper is 50Hz and 50 samples are collected per second. Low sampling rate can not only reduce power consumption, but also reduce noise interference. In order to test the effect of using adaptive hybrid filtering algorithm on improving measurement accuracy. The heart rate synchronously recorded by three channel ECG machine is selected as the reference standard to evaluate the accuracy of the. The measurement results with and without adaptive hybrid filtering algorithm are compared with the reference standard. According to the three groups of measured values of ECG machine and equipment with and without adaptive hybrid filtering algorithm, the average heart rate and standard were calculated respectively. The standard deviation of the difference between the measured value and the reference value with and without filtering algorithm is calculated. The results are shown in Fig. 7 and Fig. 8:

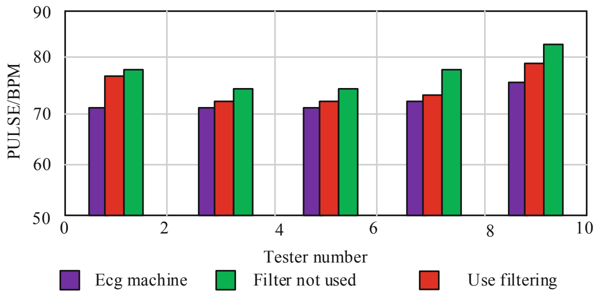

Fig. 7. Comparison of standard deviation of heart rate detection in exercise training

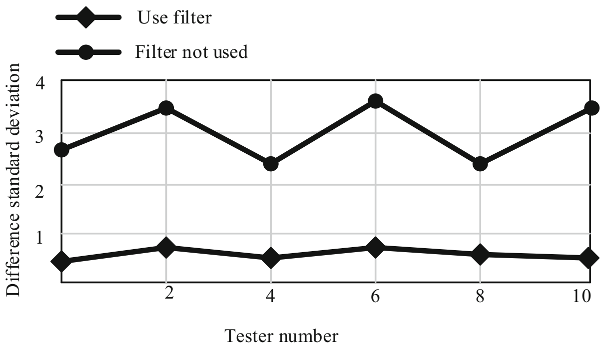

Fig. 8. Standard deviation of difference between detection filter and reference value

The mobile terminal equipped with LIS3DH acceleration sensor is placed in the front chest and coat pocket of the experimenter, and the experimental site is selected in the open outdoor. Each experimenter made three actions of running, taking off and squatting for 10 times respectively, and the interval between actions was more than 20s, so that the experimenter could adjust himself to a normal state. Among them, the take-off and squat are in-situ movements, and the experimenter is tested according to his normal state. This paper has no specific restrictions on the actions made by the experimenter, and is tested completely according to his normal state. In the test process of running, the experimenter is required to run more than 5 steps and test according to his normal running state. The vertical component analysis of acceleration sensor is used to distinguish the two actions of "take-off" and "squat". Figure 9 ~ Fig. 11 respectively represent the variation diagram of the vertical component of acceleration with time in a take-off action and a squat action. The abscissa axis represents time t (unit: s), and the ordinate axis represents the vertical component of acceleration y (unit: m/s2) (Fig. 10).

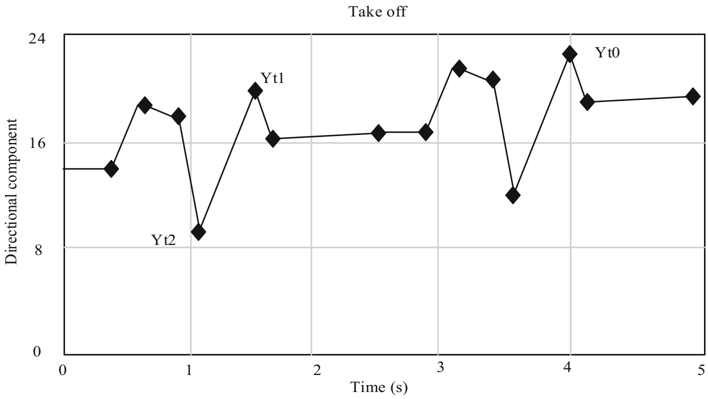

Fig. 9. Schematic diagram of monitoring amplitude of vertical component of acceleration during take-off

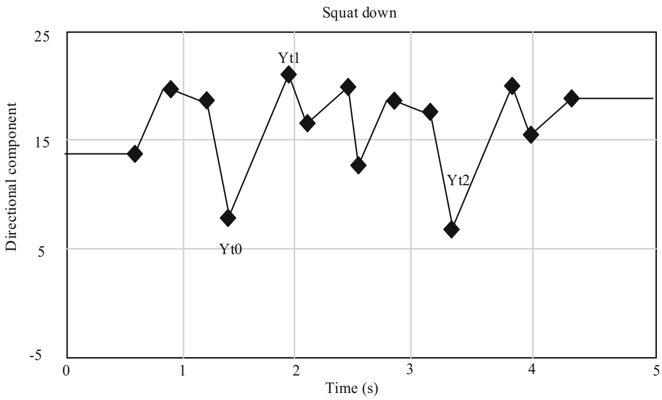

Fig. 10. Schematic diagram of monitoring amplitude of vertical component of acceleration during squatting

According to the experimental scheme designed in this paper, this paper makes statistics on the three types of actions made by a total of 12 male and female experimenters. Each person is required to repeat each action for 10 times. This paper records the correct recognition times of each person's take-off, run and squat. The experimental results are shown in Table 5 and Table 6:

To sum up, the recognition rate of the three movements in this paper has reached more than 90%. Therefore, from the correct recognition rate obtained from the experiment, it can be seen that the method proposed in this paper has a high recognition effect

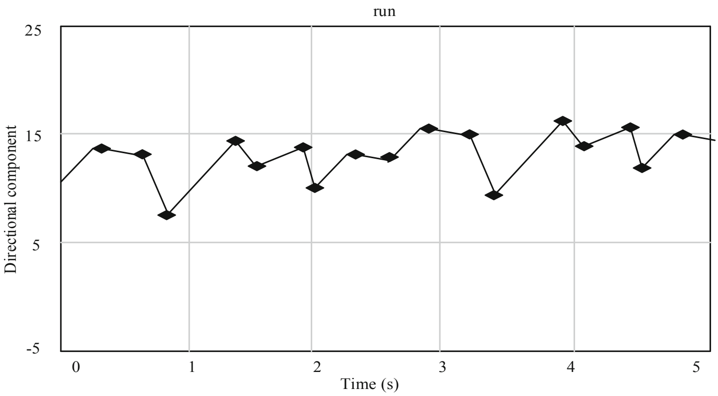

Fig. 11. Schematic diagram of monitoring amplitude of vertical component of acceleration during running

Table 5. Correct recognition times of three actions

Experimenter	Take off (correct recognition times/total times)		Run (correct recognition times/total times)		Squat (correct recognition times/total times)	
	Paper method	Traditional method	Paper method	Traditional method	Paper method	Traditional method
Female 1	9/10	6/10	10/10	6/10	9/10	6/10
Female 2	9/10	7/10	10/10	6/10	10/10	5/10
Female 3	8/10	5/10	10/10	5/10	9/10	5/10
Female 4	10/10	5/10	9/10	6/10	10/10	5/10
Female 5	8/10	6/10	8/10	4/10	8/10	6/10
Male 1	10/10	6/10	10/10	6/10	10/10	6/10
Male 2	10/10	7/10	10/10	4/10	9/10	4/10
Male 3	10/10	5/10	10/10	5/10	8/10	5/10
Male 4	10/10	7/10	9/10	5/10	7/10	6/10
Male 5	9/10	6/10	10/10	4/10	9/10	6/10
Male 6	9/10	6/10	10/10	6/10	9/10	7/10
Male 7	10/10	5/10	9/10	5/10	10/10	5/10

on the three movements of take-off, running and squatting, and has a certain practical application value.

Collect the experimental data of athletes' training intensity risk value monitoring before and after using the method in this paper under the three movements of take-off, running and squatting, and sort them into a table. As shown in Table 7.

Table 6. Statistical table of experimental results of three actions

Action	Total number of experiments	Correct recognition times	Correct rate	Number of missed reports	Underreporting rate	Number of false positives	False positive rate
Take off	120	112	93.33%	8	6.67%	1	0.83%
Run	120	115	95.83%	5	4.17%	0	0.00%
Squat down	120	108	90.00%	2	1.67%	0	0.00%
Total	360	335	93.06%	15	4.17%	1	0.28%

Table 7. Statistical table of experimental results of three actions

Number of experiments	Before use			After use		
	Take off	Run	Squat	Take off	Run	Squat
100	1.51	1.63	2.87	0.61	0.73	1.97
150	1.27	1.39	1.87	0.37	0.49	0.97
200	1.20	1.32	2.47	0.30	0.42	1.57
250	1.28	1.40	3.05	0.38	0.50	2.15
300	1.35	1.47	2.96	0.45	0.57	2.06
350	1.40	1.52	2.67	0.50	0.62	1.77
400	1.53	1.65	3.57	0.63	0.75	2.67
450	1.36	1.48	2.64	0.46	0.58	1.74

As shown in Table 7, the risk value of monitoring athletes' training intensity after the use of this method is significantly lower than that before the use, and the monitoring performance is higher. It can eliminate untrustworthy data from athletes' training data and make the monitoring results more accurate.

4 Conclusion

There is no doubt about the training effect of remote monitoring of athletes' training intensity, but there are still many places to be improved in the theoretical research, practical application and monitoring methods of training monitoring. There are various types of training monitoring, many training variables can be controlled, and the achievable training objectives are very diverse. How to make rational use of different types of training monitoring, how to accurately select and control training variables, and how to monitor training load, load response and other loads to achieve the expected training goals are very difficult problems. In addition, how to incorporate training monitoring into synchronous training and how to integrate training monitoring with special training are also important problems that need to be solved urgently.

Fund Project. School-level general project teaching and research project (brand major self-designed project) Promotion and practical analysis of happy gymnastics in the elective course of performance major (2020JYXM61).

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