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A remote consultation system for sports injury based on wireless sensor network

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Abstract

In order to improve the monitoring performance of remote consultation, a sports injury remote consultation system based on wireless sensor network is designed. Use the wearable sensors in the body area network to collect human physiological signals. Through the wireless sensor network of the wireless communication module, the collected human physiological signals are transmitted to the remote consultation module. The wireless communication module selects CC2530 chip as the core chip of the wireless communication module. A fixed partition routing algorithm based on energy balance is used to stably transmit human physiological signals. The consultation personnel of the remote consultation module make a sports injury consultation judgment based on the received physiological signal results of the human body. The system test results show that the designed system can accurately monitor various physiological indicators of the human body. The wireless sensor network energy consumption of the system in this paper is all less than 500J, the energy consumption variance of the cluster head is less than 4×10-3, and the number of surviving nodes can be guaranteed to be higher than 130. It has high communication performance of wireless sensor network. The system can accurately judge whether there is a sports injury according to the monitoring results of physiological indicators, and realize the effective consultation of sports injury.

Keywords: Wireless sensor network; Sports injury; Remote consultation system; Physiological signals; Wireless communication module; Body area network

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1. Introduction

With the improvement of economic conditions and quality of life, people begin to pay attention to health, and more and more people begin to join the team of physical exercise. Physical exercise can enhance physical fitness and prevent diseases, but it is also accompanied by the possibility of sports injuries. Sports injuries refer to various injuries that occur during exercise. The damaged tissue involves nerves, muscles, tendons, ligaments, joint capsules, skin, bone, cartilage, and can also damage internal organs and other organs. If not diagnosed and treated in time, it may lead to more serious injuries. Therefore, the research on remote consultation of sports injuries is urgent.

With a series of advantages and characteristics, wireless sensor network can cover a very wide area without excessive equipment cost and energy consumption. It can meet the data network modes such as real-time data access or automatic networking. In recent years, it has been widely promoted in many industries. At present, it has been used in natural disaster prevention, animal tracking, military and other fields, and has been continuously used in medical monitoring. Especially in patient information collection, tracking treatment and other aspects, it shows great application prospect and

promotion value [1]. The application of wireless sensor network in the remote consultation system for sports injury can accelerate the pace of medical informatization and modernization, and promote the healthy and stable development of medical undertakings in China. Wireless sensor network is a network composed of several small mobile devices connected through wireless communication technology [2]. At this stage, it is usually used for information collection and transmission. Each mobile small node includes sensor device, information receiving device and information processing device. The sensor device can be divided into light intensity sensor, temperature sensor, pressure sensor, etc. The sensor can collect and transmit information through wired transmission, infrared transmission, wireless transmission and other methods [3], among which the short-distance wireless transmission method is the most widely used.

The remote consultation system for sports injury is an interactive information system that relies on advanced communication technology to carry out remote medical consultation and diagnosis. The system is based on electronic computers, communication equipment, medical technology and equipment, and relies on multimedia means such as text, data, image, voice and other multimedia means to carry out long-distance transmission of Ref.[4] through different transmission modes, further realizing patients' medical information transmitted, and conducting consultation with patients through simultaneous interpreting of images and audio, so that patients can have face-to-face consultation with medical personnel. The remote consultation system for sports injury involves not only medical and clinical problems, but also information technology related problems such as network and database [5], and all relevant parts need to be integrated into the system. The application of wireless sensor network in remote consultation system for sports injury can not only realize the collection and transmission of important information such as ECG and EEG, but also realize the collection and transmission of physiological parameters such as heart rate and body temperature, which can effectively divide the data collection end and information processing. Patients only need to wear acquisition equipment to realize long-term monitoring and real-time analysis of physiological data, which is convenient and flexible, and solves the problems of large traditional instruments and many portable devices [6]. Telemedicine monitoring will be a major trend in the development of medical undertakings in the future. It can play a vital role in enabling more patients to receive diagnosis and treatment without time and space constraints. It is the first time to find the misdiagnosis caused by the lack of relevant indications in the traditional medical mode.

With the gradual improvement of people's living standards, human beings gradually exercise through sports. Sports events are increasing and renovated, and the number of participants is also increasing. Most sports have fierce antagonism [7], and sports injuries occur from time to time. Sports injury will have adverse effects on human health, society, family, economy and many other aspects. After the occurrence of sports injury, it is very necessary to deal with it in time and minimize the sports injury. Sports injury refers to injuries and diseases that occur when people engage in sports [8]. In sports, sports injury is more common and has unpredictable characteristics. Its occurrence and injury will not only affect human life and physical exercise, but also cause disability and serious psychological and physiological damage to the injured. Paying attention to the injury and prevention in human sports, understanding the common types of injury in sports and clarifying the preventive measures for sports injury is of great significance to promote human beings to develop the good habit of scientific exercise [9].

At present, there are many researches on wearable sensors used in remote medical monitoring. Muzny analyses the status and needs of different participants in the mobile health monitoring system [10], and studies wearable sensors with the possibility of data exchange. The method collects data from the Vandrico Wearables Database and supplements the information with additional internet searches. They classified the properties of the sensing device, connecting the device directly with the health platform. The method integrates states such as sensors, medical device authentication, and access to user data. However, the amount of patient care data is small, and the accuracy of diagnosis needs to be further improved. Ghosh et al. applied micro/nanofiber non-invasive devices in health monitoring diagnosis and rehabilitation research [11]. These devices have unique sensing capabilities that can be used to detect human vital signs such as body movement, temperature, heartbeat, respiratory rate, and blood sugar levels, and these sensors have applications in fitness-monitoring and medical diagnostics. However, the application in diagnosis and rehabilitation needs to be further improved. Although the above research methods can realize the effective collection of human physiological signals in the health monitoring system, they cannot obtain the ideal detection effect due to the influence of the communication performance in the health monitoring system. This paper studies the remote consultation system for sports injury based on wireless sensor network, and realizes the remote consultation of sports injury by using the efficient transmission performance of wireless sensor network.

2. Materials and methods

2.1.Overall system design

The overall structure of the remote consultation system for sports injury based on wireless sensor network is shown in Figure 1.

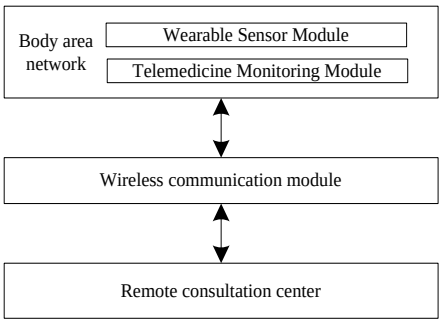

Figure 1. Overall structure of the system

Figure 1 shows the overall structure of the remote consultation system for sports injury based on wireless sensor network. It can be seen that the system mainly includes body area network, remote consultation module and wireless communication module. The wearable sensor set in the body area network is placed at the corresponding part of the human body for remote consultation of sports injury. After the wearable sensor completes the collection of human physiological signals, it is transmitted to the remote consultation module through the wireless sensor network by the wireless communication module. The consultants of the remote consultation module make consultation judgment according to the human signal results transmitted by the sensor.

2.2.System hardware design

2.2.1 Wireless communication module

The structure diagram of wireless communication module in the remote consultation system for sports injury based on wireless sensor network is shown in Figure 2.

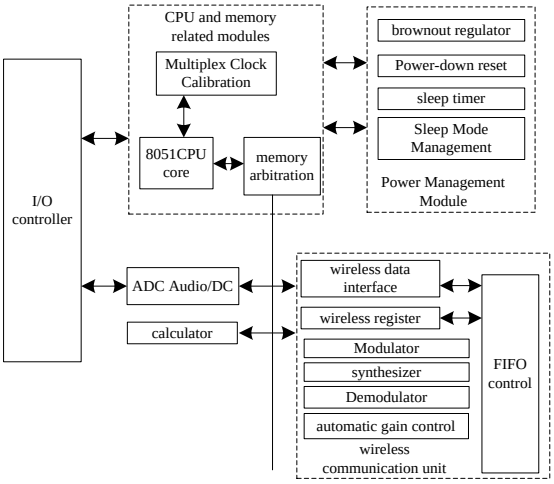

Figure 2. Structure diagram of wireless communication module

As the core of wireless communication of remote consultation system for sports injury, the wireless communication module is mainly responsible for data sending, receiving and storage, and can further process the human physiological signals collected by wearable sensors. The CC2530 chip developed by TI company is selected as the core chip of wireless communication module. CC2530 is a true system on chip (SoC) solution, which can be used in IEEE802 15.4 and ZigBee, and it is very powerful. CC2530 is internally composed of RF transceiver with excellent performance and standard enhanced 8051 CPU. CC2530 has different operation modes, which can be switched freely according to needs. It is very suitable for the low power consumption requirements of the remote consultation system for sports injury. The switching operation mode takes a short time, which further ensures low power consumption.

As shown in Figure 2, the wireless communication module can be divided into three parts: CPU and memory related unit, power management unit and wireless sensor network communication unit. The 8051 CPU core used by CC2530 runs in a single cycle, including three memory access buses (SFR, DATA and CODE／XDATA) to access SFR, data and main SRAM in a single cycle. It also includes an 18-input extended interrupt unit and a debugging interface [12]. CC2530 provides an RF wireless transceiver with excellent performance. It provides an interface between MCU and wireless equipment, which enables the wireless communication module to send and receive data, read status and automatically operate event sequence.

2.2.2 Wearable sensor module

Wearable sensor module mainly includes main node unit, blood pressure sensor, body temperature sensor and many other sensors that collect human physiological signals.

(1) Master node unit

The main node unit is installed in the wearable sensor module of the remote consultation system for sports injury. The main node unit contains a 4-core 64 bit processor to send the information collected by many sensors to the server of the system's remote consultation module. The consultant connects the wearable sensor module with sensor to his body, and the other end of the sensor is connected to the server by wireless sensor network. The temperature, heart rate and other data collected by the sensor are stored in the memory, and the data value is displayed on the ICD display.

At the same time, if the data exceeds the normal range, the alarm will be triggered. The stored value is sent to the server of the system with help. All values are stored on the server in chronological order. The monitoring personnel can log in through the login certificate to view the data of the monitored personnel, master the athlete's body temperature and heart rate during exercise in real time [13], and monitor whether there are sports injuries to effectively avoid sports accidents.

The collected data can also be used as the basis to formulate personal relevant training plans to achieve the best effect of sports training. The main node unit structure is shown in Figure 3.

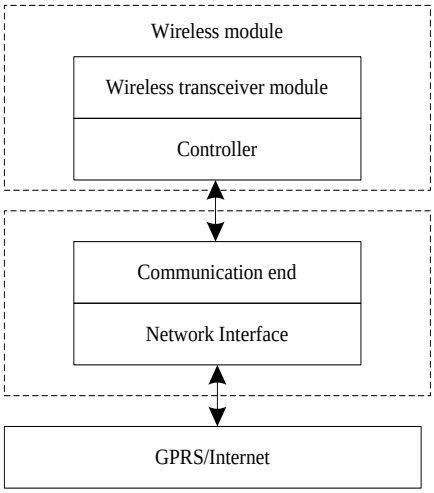

Figure 3. Main node unit structure diagram

The main node unit is mainly responsible for receiving the data from each sensor. The processor chip is required to have strong ability in data operation, data processing and communication coordination, and can process the data collected by each sensor.

(2) Blood pressure sensor

The blood pressure sensor is controlled by the control chip to restart or leak the inflation pump, one of which is sampled by ADC to obtain the AC component of the air pressure in the cuff; the other pass is ADC sampling to obtain the DC component in the cuff. The two signals can finally determine the real-time time point of systolic and diastolic blood pressure, and send the calculated systolic and diastolic blood pressure results to the master node through the RF terminal, and then the master node sends the data back to the terminal for data display and output. The pressure sensor and operational amplifier are selected to form the blood pressure sensor.

The operational amplifier is MAX4472 chip, and the pressure detection is BP01 chip. BP01 is a sensor specially designed for measuring blood pressure data. Its packaging characteristics are good. It performs well in linear output, noise control, physical stress and so on; In addition, it also improves the measurement accuracy through the method of temperature compensation. This chip is a low-power chip integrating four operational amplifiers of MAXIM company. The integrated operational amplifier A in the chip is connected to the constant current source as the constant current source of the pressure sensor. The differential input and single ended output amplification circuit is composed of operational amplifiers B, C and D, which is directly input to ADC to detect the DC blood pressure component.

After the collected data is processed by the sensor, an A/D converter processes the data into digital signal output.

(3) ECG sensor

ECG signal is special, weak and vulnerable to all kinds of interference. The ECG signal needs to be close to the detected part to be less disturbed, and the ECG signal may not be detected far away; ECG signal is generally weak, up to the order of millivolts; It is an electrical signal with low frequency, and the frequency is low, mainly below hundreds of Hz; ECG signals may be subject to strong interference, including interference caused by human body itself (human EMG interference, respiratory interference caused by breathing, etc.), or interference generated outside human body, such as surrounding power frequency interference, interference caused by poor wiring or lines, etc.

For the ECG acquisition circuit, the ECG signal is mainly obtained by the cardiac conductance link, the pre amplification is completed by ad differential amplification, and then the signal conditioning is completed by multi-level amplification, filter circuit and notch circuit [14], and then the analog / digital conversion is carried out by the single chip microcomputer, and finally the digital processing of ECG signal is completed. The signal acquisition end is also equipped with a detection lead falling off alarm system to prevent lead falling off caused by the movement of the detected person. The structure diagram of ECG sensor is shown in Figure 4.

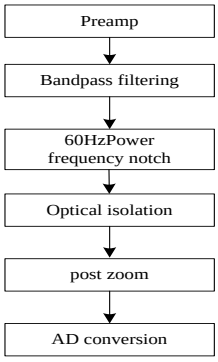

Figure 4. Structure diagram of ECG sensor

The ECG signal collected by the sensor is generally weak, which makes the impedance of the input circuit generally large and unstable. In addition, it may be subject to external electromagnetic interference. The preamplifier circuit that needs to be planned should generally be able to overcome these shortcomings, with high gain and strong anti-interference, so as to eliminate all kinds of interference that the signal may be subjected to. However, in order to stabilize the signal, the bias current and temperature drift of the circuit input should be as small as

possible to ensure reliability. Considering comprehensively, AD623 operational amplifier is selected as the main component of preamplifier. The chip is manufactured by ADI company. In addition to overvoltage protection, it is also equipped with feedback resistance and high-precision bias current. A sliding rheostat is connected between the first and eighth pins to obtain a voltage gain between 1 and 1000db. Considering the possible effect of polarization voltage, the gain should not be too outrageous.

It is reasonable to set the gain of preamplifier to 10, otherwise the amplifier may be saturated. Since the A/D conversion voltage is required to be in volt level, it needs to amplify the signal again. For secondary amplification, the gain is set to be about 100 adjustable. Op2335 is selected as the secondary amplifier, which has the characteristics of wide gain and is satisfactory in offset voltage control and zero drift. In order to eliminate high-frequency interference, low-frequency interference and power frequency interference, a band-pass filter is placed at the front end of this stage amplification circuit [15]. The filter is used to eliminate the signal noise of too low and too high frequency. Dual T active classical notch circuit is used to filter 60Hz power frequency interference.

(4) Temperature sensor

The body temperature sensor is completed by MAX6612 chip. The chip is an analog temperature sensor manufactured by Maxim company. The 5-pin SC70 package is adopted. In addition to the good characteristics of low power consumption, high precision and small volume, the working rated current is below 35 μA, the ADC is also optimized in the circuit, which is suitable for the application of this system.

After the temperature value measured by the temperature sensing module is output, it is converted by the digital to analog conversion module on the processing chip, and then the data is placed in the register. It can check the ADC register to determine whether the conversion is completed.

After conversion, the binary in the register will change accordingly. After processing, the RF terminal will send the data. The human body temperature is obtained by the above process, and then displayed in the normal form of body temperature on the terminal server. MAX6612 can directly read out the measured temperature, up to the reading mode of 9-12 digit digital value. Temperature sensor and analog-to-digital conversion unit are integrated in the chip, which is suitable for places with low power consumption requirements.

The current in standby state is generally less than 1 μA 。MAX6612 sensor has a sleep state, which is in a sleep state when it does not need to collect signals, further realizing low power consumption. The applicable voltage range is wider. The voltage range is 3.0V ~ 5.5V. Under the parasitic power supply mode, it can be powered by the data line. With the original single line interface mode, only one line is needed to realize the two-way communication between MAX6612 and microprocessor. When used, it does not need any peripheral components and has high-performance integration [16]. The temperature measurement range is -55℃-+125℃, and the accuracy is ±0.5℃ at -10℃-+85℃, which can realize high-precision temperature measurement.

Multiple MAX6612 can be connected in parallel on the only three lines to realize networking and multi-point temperature measurement, and 5V independent power supply is adopted. MAX6612 is also suitable for multi-channel and multipoint testing, which is more suitable for application in this system. The single line bus connection mode is adopted in the system. The bus mode is that the data line, address line and control line of the controller share a signal line for two-way data transmission.

(5) Acceleration gait sensor

During strenuous exercise, the acceleration of the human body can reach 12 times the gravitational acceleration, but the acceleration of the trunk will not exceed 6 times the gravitational acceleration at most. The MMA7260 chip newly developed and launched by Freescale is undoubtedly the first choice as a three-axis acceleration sensing chip. In addition to its low cost, its sensitivity is also very good.

The acceleration sensor used to collect human motion parameters will not exceed 6 times the gravitational acceleration. The acceleration sensor has the detection ability in X, Y and Z directions. The module can intelligently transmit the change of position, azimuth and moving distance. MMA7260 also provides sleep mode, which selects MMA7260 three-axis acceleration sensor to collect acceleration signal. The schematic diagram is shown in Figure 5, which is composed of MMA7260, pre filter module, signal analysis and processing circuit, power supply and wireless communication module.

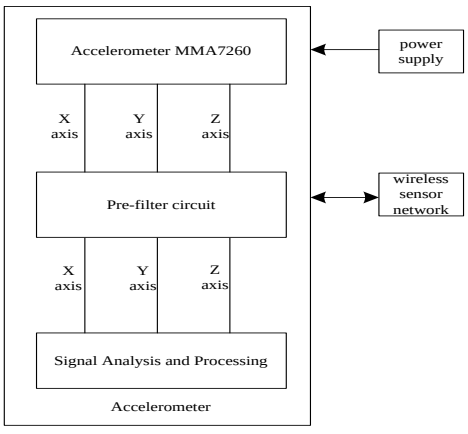

Figure 5. Structure diagram of acceleration sensor

The acceleration sensor composed of MMA7260 collects the gait acceleration data in the front and rear, left and right, up and down directions of the human body.

After noise filtering through the filter, the acceleration signal is collected and converted through the A/D converter inside the ADUC841 chip control module. Then the processed data and information obtained from the signal after corresponding processing are transmitted to the terminal computer or monitoring base station through the RF terminal.

2.2.3 MSP430 controller

The remote consultation module of the system uses MSP430F149 chip as the control chip. MSP430 series processor is a 16 bit ultra-low power mixed signal processor with RISC reduced instruction set launched by TI company. It integrates multi-functional digital circuits, modular circuits and microprocessors on a single chip to achieve the purpose of "single chip microcomputer". MSP430F149 controller has the following characteristics and advantages:

(1) Strong processing ability

MSP430 series adopts 16 bit reduced instruction set, rich destination operand addressing, source operand addressing, a large number of kernel instructions and analog instructions, a variety of operation registers and memory and high-efficiency table lookup processing instructions [17], which ensure the high efficiency of the source program.

(2) Ultra low power consumption

On the one hand, since the MSP430 series power supply voltage is 1.6 V -3.8 V, the chip current will be as low as 160μA when operating in the 1MHz clock state, even lower than 0.1μA in RAM hold mode; On the other hand, MSP430 series has a unique clock system design. It has two different clock systems: basic clock system and digital oscillator clock system. It can use either one crystal oscillator or two crystal oscillators. It can control their running state through instructions, so as to further reduce power consumption.

(3) Fast operation speed

Under the 30MHz crystal oscillator state, MSP430 series can reach the instruction cycle of 38ns; Some algorithms can be implemented under certain conditions.

2.3. Fixed partition routing algorithm for wireless sensor networks based on energy balance

The system hardware includes a wireless communication module and a wearable sensor device. Among them, wearable sensing devices include sensing nodes such as blood pressure sensors, ECG sensors, body temperature sensors, and gait sensors. The above-mentioned sensing devices need to transmit a large amount of human physiological data per minute. Therefore, it is necessary to utilize the energy balance of wireless sensor networks. Wireless sensor nodes are installed in the sensor network. Because sensor nodes have limited energy and typically cannot replace batteries or charge, sensor nodes will die when their energy is completely depleted. After the proportion of dead nodes is higher than a certain value, the wireless sensor network will stop working. Therefore, in order to prolong the service life of wireless sensors, it is necessary to keep the energy consumption of sensor nodes balanced.

Wireless sensor networks have limited energy, so low energy consumption and load balancing have become the primary objectives of routing algorithm design. Clustering routing can improve energy efficiency and balance network node load. It is an effective topology management method for wireless sensor networks.

The main idea is to select some nodes as cluster heads, so as to divide the network into clusters. The members in the cluster send the data to the cluster head, and the cluster head sends the data to the sink after data fusion. A fixed partition routing algorithm based on energy balance is proposed.

By calculating the optimal cluster radius for non-uniform clustering, combined with multi hop algorithm, the energy consumption of inter cluster communication in wireless sensor networks is effectively reduced and the "hot zone" problem caused by ordinary clustering routing is avoided. The fixed partition strategy [18] is adopted to limit the range and number of cluster head nodes to balance the network energy consumption. The energy threshold self-test mechanism of cluster head is introduced.

Each cluster only changes the cluster head under specific conditions to avoid excessive control overhead. Making full use of the residual energy of nodes and their location, the optimal node is selected as the cluster head, which further balances the energy consumption of nodes in the cluster.

When applying wireless sensor network to sports injury remote consultation system, the following assumptions are made:

(1) The sink node is far away from the monitoring area and cannot be moved after deployment. Its energy is not limited and has strong computing and storage capacity.

(2) The sensor nodes are evenly distributed in the square area and cannot be moved after deployment. All sensor nodes have the same structure, have certain calculation and storage capacity, limited energy and the same initial energy, have the unique identification of the whole network, can perceive their own residual energy team and geological location information, and the transmission power is adjustable.

(3) The communication chain in the network is symmetrical, and the influence of environmental factors on the network topology is not considered.

Because the response of the first-order model is monotonic and does not oscillate, in the first-order model, there is no concept of overshoot, and the response curve does not exceed the steady-state value, so the communication energy consumption can be calculated more accurately. The first-order energy consumption model is used to calculate the communication energy consumption of wireless sensor network in the remote

consultation system for sports injury. The calculation formula is as follows:

$$E_{T_x}(k,d)=\begin{cases} kE_e d+\varepsilon_f d^2, d<d_c \\ kE_e d+\varepsilon_m d^4, d\geq d_c \end{cases} \quad (1)$$

$$E_{R_x}(k)=E_e kd \quad (2)$$

Where $E_{T_x}(k,d)$ is the energy consumed to send k-bit data to the node with a distance of d meters; $E_{R_x}(k)$ is the energy consumed by the node to receive k bits data; E_e is the energy consumed by the node transmitting circuit and receiving circuit to process unit data; ε_f and ε_m are the energy required by the power amplifier to amplify unit data and transmit unit distance in the free space mode pad and multipath fading model respectively; d_c is the distance threshold. If the transmission distance d is smaller than the distance threshold, the power amplifier adopts the free space model, and the amplification energy consumption is directly proportional to d^2. Otherwise, the power amplifier adopts the multipath fading model, and the amplification energy consumption is directly proportional to d^4. Assuming that the data collected by the adjacent nodes in the wireless sensor network has high redundancy, the cluster head fuses the k bits data uploaded by each member into k bits packets, and then forwards them to the next cluster head.

By calculating the optimal cluster radius under the fixed partition based on energy consumption balance, the network is divided unevenly to prepare for the clustering of later partitions. The calculation of cluster radius is to balance the energy consumption of different cluster layers, so the calculation of cluster radius should start from the perspective of energy consumption. According to the calculation formula of communication energy consumption and the energy E_{da} consumed by fusing unit data, the energy $E(i)$ consumed by each layer cluster in the process of push data collection is calculated. Assuming that the redundancy of data in the remote consultation system for sports injury is limited, the data from different clusters will not be further fused, and the relay cluster head is only responsible for forwarding the data of the superior cluster head.

Assuming that the cluster radius r_i of each layer has been obtained, the number $N(i)$ of clusters contained in each layer can be calculated, and the calculation formula is as follows:

$$N(i)=\begin{cases} \left[\frac{dM}{r_i}\right],\left[\frac{dM}{r_i}\right]-r_i<\frac{r_i}{2} \\ \left[\frac{dM}{r_i}\right]+1,\left[\frac{dM}{r_i}\right]-r_i\geq\frac{r_i}{2} \end{cases} \quad (3)$$

Where, M represents the side length of the monitoring area. In partitioned clustering, it is specified that the number of cluster heads of each layer is equal to the number of clusters, so the number of $N_{non-CH}(i)$ member nodes of each layer is as follows:

$$N_{non-CH}(i)=\frac{2r_i dN(i)\times N}{M} \quad (4)$$

Where, N represents the total number of network nodes.

When the total energy consumption of each layer in the wireless sensor network is equal, the cluster radius of each layer is the best cluster radius. According to the relationship between the total energy consumption of each layer and the relationship between the sum of each layer radius and the network side length M, the equation is listed as follows:

$$\sum_{i=1}^{L} r_i = M \quad (5)$$

Through Formula (5), the optimal cluster radius under the fixed partition based on energy consumption balance is obtained to realize the energy balance in the communication process of wireless sensor networks. The fixed partition strategy is adopted to limit the range and number of cluster head nodes, solve the problems of unreasonable distribution of cluster heads and unstable number of cluster heads.

The specific process of partition clustering is divided into two steps: initial cluster head election and cluster establishment.

(1) Cluster head election

After calculating the cluster radius of each layer, the sink layers the wireless sensor network monitoring area and divides each layer into blocks of equal size (here, individual blocks in each layer are allowed to have different sizes). Since the sensor nodes have the same initial energy [19], only the node position is considered in the initial cluster head election. The sink calculates the central position of each partition, and selects the node closest to the central position as the cluster head in each partition.

(2) Cluster establishment

After selecting the cluster head, the sink selects the nearest cluster head for the non-cluster head node to join, and creates a cluster information table, including cluster ID, cluster head information and member node information. The cluster head information includes the

identification, location information, residual energy and active state of the cluster head; the member node information includes member node identification, location information, active status and data transmission time slot.

After the above operation is completed, the sink sends the cluster information broadcast to the monitoring area. After receiving the broadcast message, the sensor node queries its own cluster and determines whether it is the cluster head. If it is a cluster head, it is necessary to create and maintain a member node information table and a data transmission timeout timer to determine whether the member node dies in the communication stage in the cluster; If it is a member node, it is necessary to record the corresponding cluster head and its own data transmission time slot [20]. After that, the sensor node switches to the corresponding state: the cluster head and the member node transmitting data using the first time slot switch to the normal communication state, and other member nodes switch to the sleep state. At this point, the cluster can start normal communication.

3. Result

Wireless sensor nodes are installed in the sensor network. Because sensor nodes have limited energy and typically cannot replace batteries or charge, sensor nodes will die when their energy is completely depleted. After the proportion of dead nodes is higher than a certain value, the wireless sensor network will stop working. Therefore, in order to prolong the service life of wireless sensors, it is necessary to keep the energy consumption of sensor nodes balanced.

In order to verify the effectiveness of the remote consultation system for sports injury based on wireless sensor network for sports personnel, the designed system is applied to the sports injury remote consultation of athletes in a university. The selected colleges and universities are sports colleges. Students majoring in sports need to face a lot of sports every day.

Physical education students have a high intensity of exercise, including badminton, volleyball, basketball, tennis, Sanda aerobics and other projects. Timely consultation of sports injuries is very important. During the system test, the students of remote consultation can wear shoes at will, wear the sensor device collecting athletes' physiological signals in various parts of the human body.

The ECG sensor is worn between the chest and limbs of the human body. The ADC blood pressure sensor is worn on the upper arm of the human body. The acceleration gait sensor is worn on the thigh of the human body. The physiological data of students is collected through the above-mentioned physiological sensors. The information displayed by each part of the sensor is used as the remote consultation data of sports injury. The number of wireless sensor network nodes is set to 400.

The energy consumption results of wireless sensor network for remote consultation of sports injuries of different numbers of sports athletes using the system in this paper are shown in Figure 6.

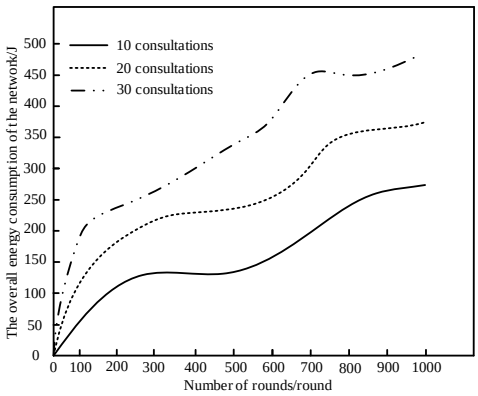

Figure 6. Overall energy consumption of wireless sensor network

As can be seen from the overall energy consumption of the wireless sensor network in Figure 6, the system in this paper can realize the transmission of information in the wireless sensor network. When the number of remote consultation personnel is different, the energy consumption of the wireless sensor network in this system is less than 500J, which means that in the process of remote consultation of sports injury, under the same number of rounds, the system in this paper can minimize the energy consumption of wireless sensor network communication.

Next, the variance of cluster head energy consumption is analyzed to judge whether the cluster head energy consumption is balanced. Taking the maximum and minimum energy consumption of cluster head node, the variance of cluster head energy consumption can be calculated according to the variance formula. Taking 10 rounds of samples continuously and randomly, it can obtain the energy consumption variance curve of the cluster head of the wireless communication network adopted by the system in this paper, as shown in Figure 7.

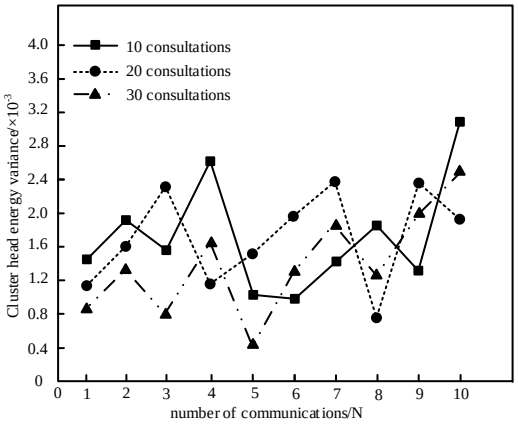

Figure 7. Variance of cluster head energy consumption

Figure 7 shows that the system in this paper can not only realize the transmission of information in wireless sensor networks, but also ensure the balance of information in wireless sensor networks. The variance of cluster head energy consumption of wireless sensor networks is less than 4×10-3 when the number of remote consultation personnel is different. It shows that the system in this paper can better balance the energy consumption in different areas of wireless sensor networks, and has high communication performance of wireless sensor networks.

The balance of node energy consumption is the most important factor to prolong the network life cycle. When different personals make remote consultation of sports damage, the life cycle curve of wireless sensor network is shown in Figure 8.

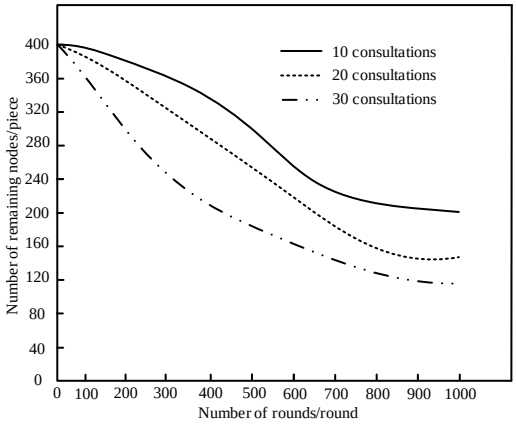

Figure 8. Life cycle of wireless sensor network

Figure 8 shows that With the increase of the number of rounds, the surviving nodes of the wireless sensor network gradually decrease. However, after 1000 rounds, the system in this paper can still ensure that the number of surviving nodes is higher than 130, which can ensure the normal overhead of wireless sensor network energy consumption. The wireless sensor network used in the system of this paper can still ensure a large number of surviving nodes and maintain a long life cycle after many rounds. The main reason is that the routing algorithm designed in this paper is based on energy balance. In this paper, the problems of excessive communication energy consumption and control overhead between clusters, large fluctuation in the number of cluster heads and uneven distribution of cluster heads in wireless communication networks are fully considered, and a fixed partition routing algorithm based on energy balance is proposed. Non uniform clustering combined with multi hop algorithm can reduce the energy consumption of inter cluster communication and avoid the problem of "hot zone". The fixed partition strategy is adopted to limit the range and number of cluster head nodes. The cluster head energy self-checking mechanism is introduced to reduce the control overhead of the network. At the same time, the optimal node is selected as the cluster head by using the node residual energy and its geographical location. Simulation results show that the algorithm has good performance in the overall energy consumption, load balancing and life cycle of the network.

This system is used for remote consultation of sports injury for 10 athletes. The forward direction of human body is set as the positive direction of axial acceleration, the left turning direction of human body is regarded as the positive direction of axial acceleration, and the upward moving direction of human body is regarded as the positive direction of axial acceleration. In this paper, the system uses the acceleration gait sensor to obtain the abnormal gait waveform of an athlete, as shown in Figure 9.

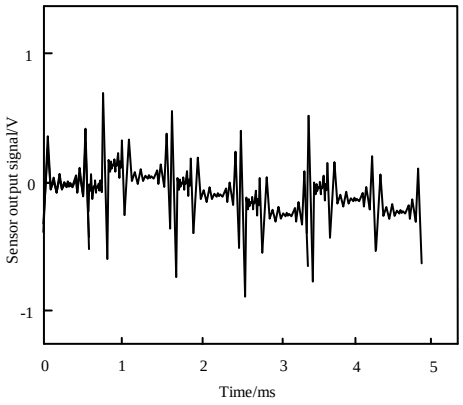

Figure 9. Waveform of abnormal gait

Through the system test results in Figure 9, it can be seen that the gait abnormal waveform of sports athletes can be effectively obtained by using the system in this paper. When the waveform displayed by the acceleration gait sensor is abnormal, it indicates that the sports athlete may have sports injury. The doctor of remote consultation needs to formulate a specific treatment plan for sports injury according to the specific content displayed by the waveform of abnormal gait.

The results of remote consultation of body temperature, blood oxygen saturation and blood pressure of 10 athletes using the system in this paper are shown in Table 1.

The test results of the system in Table 1 show that the monitoring results of various physiological indexes of athletes can be effectively obtained by using the system in this paper. There is little difference between the monitoring results of physiological indexes of athletes and the actual index results. It is verified that this system has

high monitoring performance and can obtain accurate physiological indexes of athletes. According to the monitoring results of athletes' physiological indexes, it can clarify the sports injury results of sports athletes, and realize the effective consultation of sports injury.

The monitoring results of the system test are handed over to 100 experts. The statistical experts' actual application of the remote consultation system for sports injury is shown in Table 2.

According to the experimental results in Table 2, most experts believe that the system has high operability and good remote consultation effect. Experts generally believe that the system has convenient remote consultation performance, can grasp the sports injury of athletes at any time, and clarify the safety problems of athletes in the process of sports.

100 sports athletes are selected as the survey object. In the one month long-distance consultation of sports injury, the injury of team members shows a significant downward trend, and the overall competitive level of sports athletes is improved. In terms of robustness, convenience, safety, accuracy and operability, the evaluation results of the staff after the consultation were very satisfactory, all higher than 68%. Athletes say that through the sports injury remote consultation system, they can obviously feel that the safety awareness has been improved in the training process, promote the action cooperation ability among athletes, and improve the overall cohesion of athletes.

Table 1. The monitoring results of remote consultation the system in this paper

Athlete serial number	Monitor body temperature/℃	Actual body temperature/℃	Monitor blood oxygen saturation/%	Actual blood oxygen saturation/%	Monitor pulse /time	Actual pulse /time
1	36.8	36.7	97	96	82	81
2	36.7	36.8	96	96	76	75
3	36.5	36.4	96	95	78	77
4	36.6	36.5	97	96	77	77
5	32.4	36.5	96	95	75	75
6	36.5	36.4	97	96	74	74
7	36.6	36.5	96	95	81	81
8	36.7	36.6	96	95	83	84
9	36.8	36.7	97	96	84	83
10	36.3	36.4	96	95	85	86

Table 2. Feedback on the effect of remote consultation

Test indicators	Dissatisfied/%	Satisfy/%	Basically satisfied/%	Very satisfied/%
Robustness	1	3	20	76
Convenience	1	2	19	78
safety	1	5	25	69
Precision	1	3	15	81
Operability	1	3	20	76

4. Discussion

This paper studies the remote consultation system of sports injury based on wireless sensor network, and uses wireless sensor network to realize the remote consultation of sports injury, so as to provide basis for the timely treatment of sports injury. When human beings engage in sports, they need to start from the following aspects to avoid sports injuries as far as possible.

(1) Understand the prevention knowledge of sports injury and correct the careless thought of numbness

First of all, in terms of ideology, we should pay enough attention to the prevention of sports injuries. In the process of participating in sports, we should always pay equal attention to prevention and preventive measures. When trying to contact unknown sports content or participate in new sports, we should first understand the technical characteristics of the project and master the injuries suffered by body parts when participating in the activity, if possible, you can also wear protective tools, etc. Secondly, we should avoid being impatient, arrogant and adventurous in training or sports, so that the probability of sports injury will be minimized.

(2) Make adequate preparatory activities

There must be sufficient preparatory activities before sports activities or sports training. Each physiological system in the human body can be better adjusted after activity preheating, and can better adapt to the state before sports. Let the body better transition and pave the way from "static" to "moving", so as to effectively reduce the probability of sports injury.

(3) Strengthen medical self-supervision and improve self-care awareness

In the process of participating in sports, human beings need to strengthen their self-monitoring ability, master simple medical means and medical knowledge, and face up to their physical condition and sports state. Through simple self-monitoring, potential sports injuries can be found in advance. Self-medical supervision shall be formulated according to their own physical conditions and their ability to bear, comprehensively consider their own physiological and psychological indicators, and try their best to minimize the probability of sports injury until it is eliminated.

Most of the sports injuries in human sports belong to closed sports injuries. The causes of sports injuries are various. There are great differences in the injuries of different sports to various parts of the human body. To clarify the causes of sports injuries, it is necessary to strengthen human health education and reduce the occurrence of sports injuries. When human beings carry out sports, they need to fully cultivate human health awareness, understand and prevent sports injuries, and establish the concept of modern sports. We should strengthen the preparation activities before exercise and the relaxation exercise after exercise, improve the timeliness of the preparation activities, avoid and reduce the occurrence of sports injury, pay attention to the relaxation exercise after exercise, and prevent delayed muscle soreness after exercise. At the same time, the relaxation activity can make the stress response of body temperature, heart rate, respiration and muscle return to the normal level before exercise as soon as possible, and help relieve mental stress.

5. Conclusion

Physical activity is an important way to improve the physical and mental quality of the human body. People are prone to sports injuries during sports activities. Finding out the possible causes of sports injuries and reasonably avoiding the occurrence of sports injuries is of great significance to ensuring the safety of human sports.

(1) In order to improve the performance of sports injury remote consultation, improve the data transmission performance of the consultation system. In this paper, the wearable sensors in the body area network are used to collect human physiological signals. Then through the communication module of the wireless sensor network, the physiological signal data is quickly transmitted to the consultation module. And a fixed partition routing algorithm with energy balance is given to ensure the transmission performance of human physiological signals. This can further improve the accuracy of the consultation.

(2) It can be seen from the experimental results that the energy consumption of the wireless sensor network of this system is lower than 500J, and the energy consumption variance of the cluster head is lower than 4×10-3, which effectively improves the data transmission performance. After the consultation, the evaluation results of the staff were all higher than 68%, and the designed system improved the comprehensive performance of the remote consultation.

(3) The telemedicine monitoring system solves a series of problems existing in traditional medical services to a certain extent. In order to further promote the effective application of wireless sensor networks in remote medical monitoring systems, relevant personnel must continue to study and summarize experience, and overcome various problems in practical application. Using the wireless sensor network-based sports injury remote consultation system, actively promote the healthy and stable development of my country's medical industry.

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