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An Early Warning Method for Volleyball Players with Human Bioelectric Energy

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Abstract. Bioelectric energy is a weak electric current generated by the human body itself, and the change in its value can indicate human injury, which can be used as a competitive physical injury judgment information. However, in the past, bioelectric energy measurement was mainly based on the standard voltage of 220 V, and it was not possible to conduct follow-up tests, so the scope of application was limited. Photovoltaic equipment in new energy has the characteristics of being easy to carry and can meet the needs of bioelectric energy testing at the theoretical level. In order to improve the application depth of new energy equipment and improve the safety of volleyball competition. Therefore, from the perspective of new energy, this paper tests the human bioelectric energy, collects current, voltage and power flow signals, combines the different functions to reduce the data dimensionality, calculates the abnormal changes of bioelectricity, and forms an abnormal data set. Finally, according to the injury characteristics of the human body, the volleyball economy is given an early warning. The results show that photovoltaic cells can meet the measurement requirements of human bioenergy, and the detection accuracy rate of joint injury, negative emotion, muscle strain and respiratory system injury reaches 80~83%, the abnormal electrical energy recognition rate reaches 90~95%, and the athlete satisfaction rate reaches 98%, and the wearing time is 1~3 months. Therefore, photovoltaic equipment can meet the identification requirements of human bioelectricity and has practical value in assisting competitive training and injury early warning.

Key words. Human Bioelectricity, Volleyball Players, Sports Injuries, Early Warning Methods, Photovoltaic Equipment.

1. Introduction

When the balance between the amount of exercise and the amount of training is broken, overtraining may occur, resulting in competitive injuries, non-functional competitive injuries, and persistent competitive injuries, which manifest in joint injuries, muscle strains, and negative psychological emotions. Some scholars believe that. Human bioelectricity plays an important role in athletic injuries. By identifying abnormal currents in bioelectricity [1], [2]. Ability to find the direction and extent of human injury. and timely intervention, but human bioelectric testing. The analysis is mainly carried out by large-scale equipment. Alternatively, the measurement can be carried out via a terminal mobile device. Both have a large demand for energy consumption, so athletes' competitive injuries are mainly detected in rehabilitation centers. Human biocurrent is a weak current, and its abnormal features appear for a short period of time and cannot be identified by short-term monitoring. Therefore, some scholars believe that the application of photovoltaic equipment to the early warning of competitive injuries can continuously observe athletes and detect the timing of injuries in volleyball players, which is convenient for later data analysis. Studies have shown that the incidence of old sports injuries is high, mainly due to the lack of intervention in the early stages, resulting in negative emotions such as bone hyperplasia, muscle strain, or anxiety in athletes [3], [4]. Therefore, some scholars believe that the use of photovoltaic equipment in new energy to identify human bioelectricity has the characteristics of continuity and permanence, and can detect abnormal conditions of bioelectricity in time [5], [6] and provide early warning. Some scholars have also proposed to collect and sort out athletes' bioelectric signals, build an early warning platform, and realize the overall early warning data by comparing athletes' previous injury data. Among them, key indicators, such as cardiopulmonary function, muscle stretching, and old injuries, are used to judge dichotomous signals, simplifying the identification complexity of abnormal signals. Some scholars believe that the continuous transmission of human bioelectric signals will form data redundancy and affect the data collection of photovoltaic equipment, so it is recommended to regularly delete data [7], [8] and require photovoltaic equipment to have continuous power supply capacity. Some people believe that photovoltaic equipment should use a combination of stationary batteries and photovoltaic charging to collect signals, and set a waiting time to extend the use time of photovoltaic equipment during the signal collection process [9], [10]. On the basis of the above analysis, this paper analyzes the abnormal signal of human bioelectricity from the perspective of photovoltaic equipment, monitors the bioelectric data of volleyball players in daily training and competition, and compares the abnormal information. First of all, radio technology is used to collect human bioelectric signals and data, and store them on the remote server. Then, the

differentiation function is used to simplify and compare the data, eliminate the signals that match the historical data, and record the abnormal data. Then, the regression equation of the photovoltaic equipment itself is used to carry out signal ranking and analysis, find out the location of human damage, and early warning and comparison of damage. In the research process, it is necessary to use intelligent algorithms and photovoltaic equipment for data processing and realize the early warning of photovoltaic equipment for injury through the remote server, which is to expand the application of new energy equipment in competitive injuries and reduce the competitive injury rate of athletes.

2. Human Bioelectric Energy in the Early Warning Process of Competitive Injury of Volleyball Players

A. Photovoltaic Equipment for Human Bioelectricity Testing

There is a phenomenon of current decay in bioelectricity, and a large current will appear after the human body is damaged, it will act with the sensor of the photovoltaic equipment to form an abnormal current, but the human bioelectricity in the normal position will decline, resulting in the sensor tracking the target much lower than the abnormal signal. The tracking of abnormal signals by the sensors of photovoltaic equipment is complementary to the normal signals, and the tracking analysis is carried out through iterative deviation mean estimation. On the basis of multi-human feature fusion, the problem of long time to track abnormal bioelectricity in photovoltaic equipment was studied, and damage early warning was carried out according to the tracking results, and its mathematical expression is shown in Equation (1).

$$f(s_i)=\left[x_i,x_i^*,y_i,y_i^*,d_{xi},d_{y_i},\theta_i\right]^{\mathrm{T}} \tag{1}$$

In Equation (1), it (x_i,y_i) represents normal bioelectricity and sensor bioelectricity, x^* and abnormal y^* bioelectricity. d_x, d_y and θ the evaluation basis and adjustment coefficient of biopotential respectively, and finally, the test of abnormal biopotential is shown in Equation (2).

$$S_j = A\cdot s_i+\Delta w_i \tag{2}$$

Equation (2) represents the processing process of the abnormal signal, where S_i the sum S_{i+1} is the near value of the occurrence of the abnormal bioelectricity; A amplify the matrix for abnormal signals; w_i It is the extraction of abnormal signals, mainly to remove heartbeat, and breathing, etc., and $w_i\sim N\left(0,\sigma^2\right)$. The study enhances the robustness of biopotential tracking by fusing multiple characteristics such as respiration, heartbeat, and blood pressure, but it may also increase the complexity of PV device tracking and prolong the computational time. In order to balance the robustness and efficiency of tracking, the data can be divided into two parts, the likelihood and texture characteristics of abnormal signals can be calculated, and the human bioelectricity model can be established. The human bioelectric signal is quantified as v_i, p_i, and I_i the power flow, voltage and current are calculated respectively to form the spatial description $N_h=v_i\cdot p_i\cdot I_i$ of bioelectricity and form the signal source of human bioelectricity. Hypothesis 1: Human bioelectricity is characteristic, $N_h^*\to\left(\{x_i\}_{i=1}^{N^*}\right)$ and the location of the abnormal signal is x_0 calculated as the x_0 signal distribution at the center point $r_c^{(N^*)}$, as shown in Equation (3).

$$r_c^{(h)}=f\sum_{i=1}^{N^*}k\left(\frac{\|\Delta x_i\|}{d_{x0}}\right)\to\delta\left[p(x_i)-\Delta h\right] \tag{3}$$

In Equation (3), $\Delta h=1,2,\cdots,n$ the signal height of the bioelectricity is the convergence $f=\left[\sum_{i=1}^{N^*}k\left(\left\|\frac{\Delta x_i}{d_{x0}}\right\|^2\right)\right]^{-1}$ of the biopotential signal, which represents the $k\left(\|x_i\|^2\right)$ regional change of the bioelectricity. $\delta\left[p(x_i)-\Delta h\right]$ is the association between the abnormal signal and the database signal, where $p(x_i)$ the x_i amplification is respectively. The biopotential signal characteristics can reflect m_1 the similarity between the location of the m_2 injury and the cause of the injury, and the above causes are suggested by qualitative description and quantitative analysis. The similarity function of the damage warning can be expressed as $\mathrm{Similarity}(m_1,m_2)$, calculated as shown in Equation (4).

$$\mathrm{Similarity}(m_1,m_2)=(\omega_i\to\omega_j)\times(\widehat{\sigma_i}+\sigma_j) \tag{4}$$

In Equation (4), σ the difference between the abnormal biopotential and the standard biopotential is the ω transverse and longitudinal signals collected by the photovoltaic device. The similarity analysis between abnormal biopotentials is mainly calculated by the Barcol coefficient, the damage characteristics r_y and the cause characteristics g_y, and the similarity dataset $\varphi_i\left(r_y,g_y\right)$ and cause likelihood function $\varphi\left(Z_k|\ S_k\right)$ are formed in the photovoltaic equipment, as shown in Equation (5).

$$\begin{cases}\varphi_i\left(r_y\to g_y\right)=\sum_{h=1}^{m}r_y^{(h)}\cdot\max g_y^{(h)}\\ \varphi\left(Z_i|\ S_i\right)=\sin(\theta)\cdot\delta_i\exp\left(\frac{\varphi_i\left(r_y,g_y\right)}{\sum\delta_i^2}\right)\end{cases} \tag{5}$$

In Equation (5), the Z_i signal recorded by the photovoltaic equipment at all times is the δ_i Gaussian variance of the bioelectric signal.

B. Early Warning of Competitive Injuries of Volleyball Players

The damage target $\varphi^*(Z_k|\ S_k)$ is described by current, voltage, and power flow characteristics to determine the location and cause of the damage, as shown in Equation (6).

$$\varphi^*(Z_i|\ S_i)=\frac{\sin(\alpha)\cdot\varphi_c(Z_i|\ S_i)+\cos(\beta)\cdot\varphi_l(Z_i|\ S_i)}{\tan(\gamma)\cdot\varphi_s(Z_i|\ S_j)}+\Delta\varphi \quad (6)$$

In Equation (6), the $\sin(\alpha),\cos(\beta),\tan(\gamma)\simeq 1$ coefficient representing the location, cause and type of injury is based on the athlete's personal database. The tracking effect of biopotential becomes more and more obvious with the increase of current, but blindly increasing the current will also cause the energy consumption of photovoltaic equipment to increase, or the equipment may be damaged, and even burn. Therefore, the adaptive selection of current signals was studied, and the operation of reducing current and increasing voltage was carried out on complex biopotential signal markers, so as to ensure the real-time tracking of human bioelectricity., therefore $w_i \sim N(0,\sigma^2)$, and N the function of and presents a monotonic decrease φ, as shown in Equation (7).

$$v_i=\frac{P_i}{\sum v_i+\exp\left[(\Delta\varphi)\times\lambda_i\right]} \quad (7)$$

In Equation (7), $v=\sigma$ it N is necessary to select the coefficient P_i with λ_i the appropriate value and be in σ and N within the appropriate range, so the current and voltage should be balanced to obtain the adaptive adjustment function of the abnormal bioelectricity, as shown in Equation (8).

$$\varphi^*(Z_i|\ S_i)=mean\{rand\left(\frac{m_N}{1+\exp\left[(\Delta\varphi_i)*n_N\right]}\right)\} \quad (8)$$

In Equation (8), n_i the $k+1$ anomalous signal quantity $rand(\cdot)$ is a random function, and when the abnormal signal appears, the observation likelihood function is estimated, and finally, the cause and location of the abnormal signal are determined, and the damage warning is carried out.

C. Tracking Conditions for Photovoltaic Equipment

In order to balance the tracking accuracy and working power of the photovoltaic equipment on the human bioelectricity, standby constraints are added on the basis of abnormal signal recognition to keep the photovoltaic equipment in standby mode. The normal bioelectric signal is discarded and eliminated by repeated sampling, and the abnormal signal is retained and replicated. Through the method of bioelectric fusion, the photovoltaic equipment sets the anomalous range of bioelectricity, forms a bioelectric ensemble, and calculates the local optimal solution of the abnormal signal, and the bioelectric tracking process is shown in Figure 1.

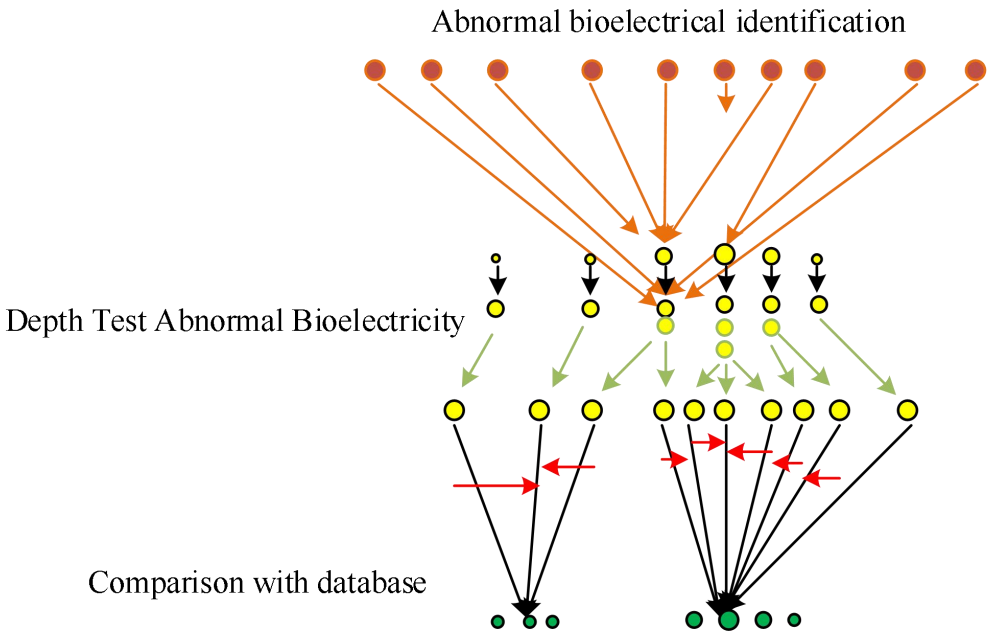

Figure 1. The Search Process of Human Bioelectric Signals

In Figure 2, in the process of searching for the human biological chain, small signals are gradually eliminated, and large signals are mainly searched, and the optimal search results are finally formed according to different search ranges and search conditions, and the iterative parameters of the signals and the comparison results of signal anomalies are calculated between different searches. If the target location of the human bioelectricity is determined, the cause of the occurrence of the bioelectricity is calculated $p_j^{(i)}$, and the calculation method is shown in Equation (9).

$$p_j^{(i)} = \left[\sin(\alpha) \cdot \cos(r_c) \cdot \left(Z_i \middle| S_j^{(i)} \right) + \gamma_k \cdot r_s \left(Z_i \middle| S_i^{(i)} \right) \right] \quad (9)$$

In Equation (9), the sum of the fusion coefficients of the location and cause of the damage α_i γ_i is adjusted adaptively by calculating the similarity, as shown in Equation (10).

$$\begin{cases} \alpha_i = \Delta\varphi_c / \sum(\varphi_c + \varphi_s), 1 \\ \gamma_i = \Delta\varphi_s / \sum(\varphi_c + \varphi_s), 0 \end{cases} \quad (10)$$

In Equation (10), φ_c and $\begin{cases} \alpha_k = \varphi_c / (\varphi_c + \varphi_s) \\ \gamma_k = \varphi_s / (\varphi_c + \varphi_s) \end{cases}$ represent the current and voltage represented by the damage, and , respectively, it $\varphi_c = \varphi(r_y, g_y)$ $\varphi_s = Similarity(m_1, m_2)$ means that the current, voltage and power flow signals identified by the photovoltaic equipment itself are recorded in the server, and the early warning analysis is carried out, and the final output early warning result $\sum y_i$ is shown in Equation (11).

$$\sum y_i = \left[\frac{\sum_{i=1}^{N} x_i \cdot \Delta H\left(\frac{x_i - y}{b} \right) \to p(x_i)}{\sum_{i=1}^{N} H\left(\frac{x_i - y}{b} \right) \cdot p(x_i)} \right] + \Delta\lambda \quad (11)$$

In Equation (11), x_i the biopotential signal collection is centered x ; N is the fluctuation of bioelectricity; d Represents the amplitude of fluctuations in abnormal signals.

3. Early Warning Cases of Competitive Injuries of Human Bioelectric Energy in Volleyball Players

A Introduction to the Athletes' Competition

Male volleyball players aged 20~24 were selected as the research subjects, with a weight of 112kg, a height of 1.78m, and a 10-year sports career. The photovoltaic equipment is a polycrystalline silicon tube, the light energy conversion rate is 75%, the power is 12W, the voltage is 6V, the current is 0.4A, the signal transmission is WIFI encryption, the server is IBM server, the storage space is 10G, and the CPU is i7. The test time is 30 days, the test period is 24 hours, and the results of bioelectric energy judgment are verified by comparing photovoltaic equipment and clinical testing equipment. Among them, the clinical testing conditions are as follows.

Table 1. Methods for Detecting Human Injuries

Index	Test Method	Test Instruments
Complete Blood Count	Blood Counts	Beckman Coulter (United States)
Creatine Kinase (CK), Blood Urea (BU)	Biochemical Analysis	Beckman Coulter Fully Automated Biochemistry Analyzer
Testosterone (T), Cortisol (C)	Chemiluminescence Method	Beckman Coulter Chemiluminescence Immunoassay Analyzer (United States)
Blood Lactate	Whole Blood Test	YSI-1500 Blood Lactate Tester (United States)
Folic Acid, Vitamin B12 (VB12), Ferritin	Microparticle Enzyme Immunization	BeckmanCoulter DXZ800 Automatic Immunoassay Analyzer (United States)
Fe2+、UIBC、TIBC	Colorimetry	Olympus AU400
K+、Na+	Enzymatic Method	Olympus
Cl-	Colorimetry	Olympus

At the same time, a 3D scan of the athlete's body is carried out to form a digital model, as follows:

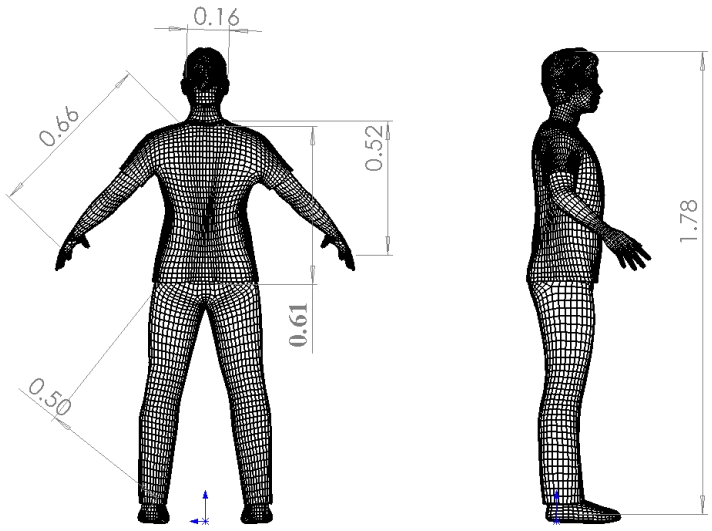

Figure 2. Digital Model of the Athlete

Through the construction of digital models of athletes, human bioelectric analysis at the edge of the later stage provides a basis for later research.

B The Early Warning Effect of Human Bioelectricity on Competitive Injuries

According to the human bioelectric situation of athletes, early warning of sports injuries is carried out to identify abnormal bioelectric signals, as follows.

Table 2. Changes in Human Bioelectric Signals

Damage	Normal Bioelectricity			Abnormal Bioelectricity		
	Current	Voltage	Tidal Current	Current	Voltage	Tidal Current
Joint	0.891	0.223	-0.902	1.282	-0.794	-0.488
Muscles	-0.304	1.018	0.796	-1.219	0.810	0.409
Sentiment	0.590	-0.963	0.345	1.208	-0.886	-0.322
Breathe	1.981	3.072	3.773	1.039	1.981	4.989
Heart	0.512	3.350	0.761	0.761	3.865	4.617
Liver and Kidneys	1.688	3.050	0.995	3.898	3.050	0.969
Note: Average profile factor = 0778, the energy consumption reduction of testing equipment is 10~15KJ.						

As can be seen from Table 2, photovoltaic equipment can effectively identify the current and voltage of abnormal bioelectricity, and judge the location of its damage to joints, muscles, or negative emotions according to the changes of current, voltage and power flow, and monitor the respiratory system, heart, liver and kidney to achieve the corresponding predetermined effect, and through the change of each coefficient, it can be seen that its overall descriptive nature is 0.778, which meets the early warning requirements and can achieve the preliminary early warning effect. However, the bioelectric abnormality cannot completely determine the location of the injury, and it is necessary to judge it in combination with the health database and dig deep into the reasons, as follows: 1) The training method is unreasonable, mainly because it is not designed for athletes, resulting in excessive physical consumption of athletes, and most of the players participate in training as sparring partners, and the training pressure of athletes is relatively large, resulting in joint damage and muscle strain. 2) Due to the frequent competitions, when athletes do not perform well in training or competitions, athletes will be transferred to the provincial team, resulting in negative emotions. 3) The effect time is long, and the athlete has old injuries, so the heart, liver and kidney are damaged. At the same time, the outliers of the athletes' bioelectric signals were compared, and combined with the clinical biological test, an early warning qualitative table was formed, and the specific results are as follows.

Table 3. Warning Range of Human Bioelectric Energy for Volleyball Players

Index	Standard	Photovoltaic Equipment		Clinical Examination
		State	Correspondence with Current and Voltage	
Hemoglobin (g/L)	24~55	Normal	0.62~0.63,0.33~0.34	30.1±0.81
Creatine Kinase (U/L)	25~55	Abnormal	0.64~0.63,0.34~0.35	62±0.11
Blood Urea (mmol/L)	20~90	Normal	0.62~0.63,0.35~0.36	3.72±1.35 PM
Testosterone (ng/dl)	21~69	Normal	0.61~0.62,0.33~0.34	46±15.23

Cortisol (μ g/dL)	20~94	Normal	0.60~0.61,0.33~0.34	4/16/4±4/01 AM
Blood Ammonia (μ mol/L)	9~33	Abnormal	0.66~0.68,0.31~0.34	52±0.15
Folic Acid (ng/ml)	7~24	Normal	0.69~071,0.34~0.37	5.05±1.65
Ferritin (ng/ml)	8~85	Normal	0.62~0.63,0. 31~0.35	47.40±30.52
Iron ion (μ mol/L)	7~55	Normal	0.62~0.63,0.32~0.37	6.15±6.77 PM

As can be seen from Table 3, the monitoring of human bioelectricity by photovoltaic equipment is mainly qualitative analysis, and no specific value is obtained, so follow-up biological detection is required. The overexercise of athletes is a long-term process from normal fatigue to normal recovery, to abnormal fatigue, from functional early overtraining to non-functional early overwork, and finally back to the recovery stage of excessive exercise, so the monitoring of early warning indicators is also continuous. By analyzing the correlation changes in athletes' competitive injury performance, training data, independent skills, practical skills, physical condition, mental state, brain, self-perception, physical diseases, etc., and constructing a health database, the relevant parameters of excessive exercise that can be detected in advance can be determined. After the analysis of the bioelectric signal, a preliminary abnormal warning is formed. In addition, photovoltaic equipment will identify human bioelectric signals to form a vivid and observable signal, as shown in the figure below.

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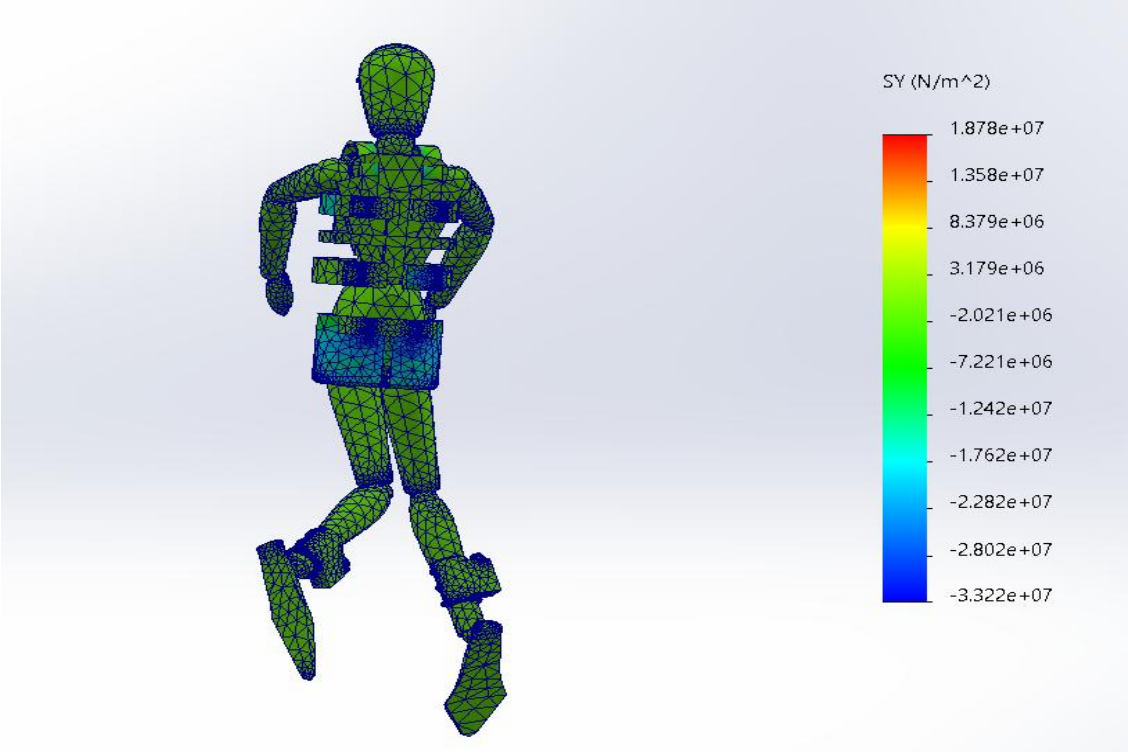
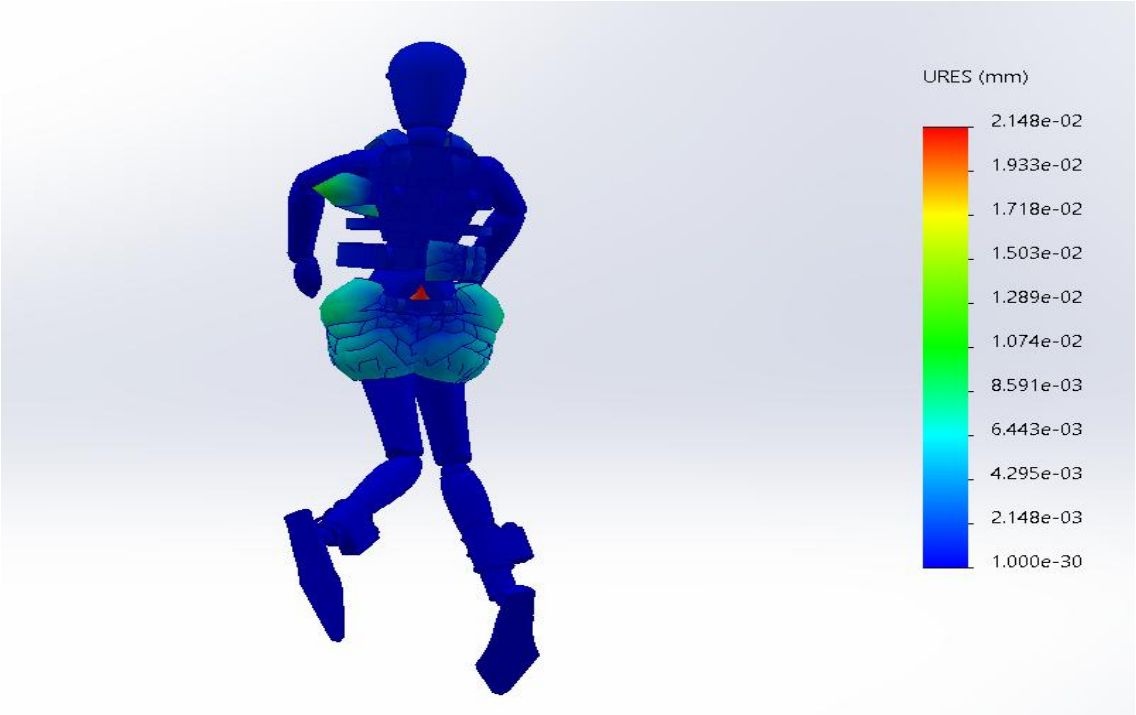


A Photovoltaic Device Detects a Bioelectric Signal



The Result of the Biopotential Signal Amplification
Figure 3. Biopotential Signals Detected by Photovoltaic Devices

From the data analysis in Figure 3, it can be seen that the photovoltaic equipment discovers the injury of athletes through the identification of human bioelectric abnormal signals, and forms a damage early warning map through the transformation of binary signals, which is converted into three-dimensional data, which provides a more intuitive method for later early warning, so the human bioelectric monitoring of photovoltaic equipment has an auxiliary role, which can not only provide a basis for clinical biological detection, but also provide a basis for image recognition, and is the basic data for economic damage early warning.

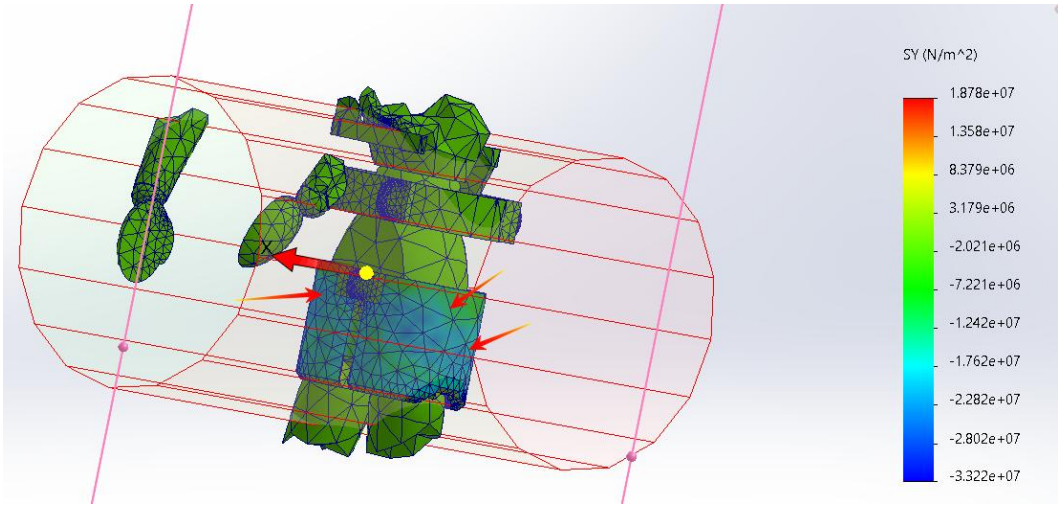
C Early Warning of Human Bioelectric Signals for Competitive Injuries

After the early warning problem is identified, the PV device can provide simple first aid measures and first aid strategies based on its own historical data to ensure the safety of training, and the specific test results are shown in the following Table 4.

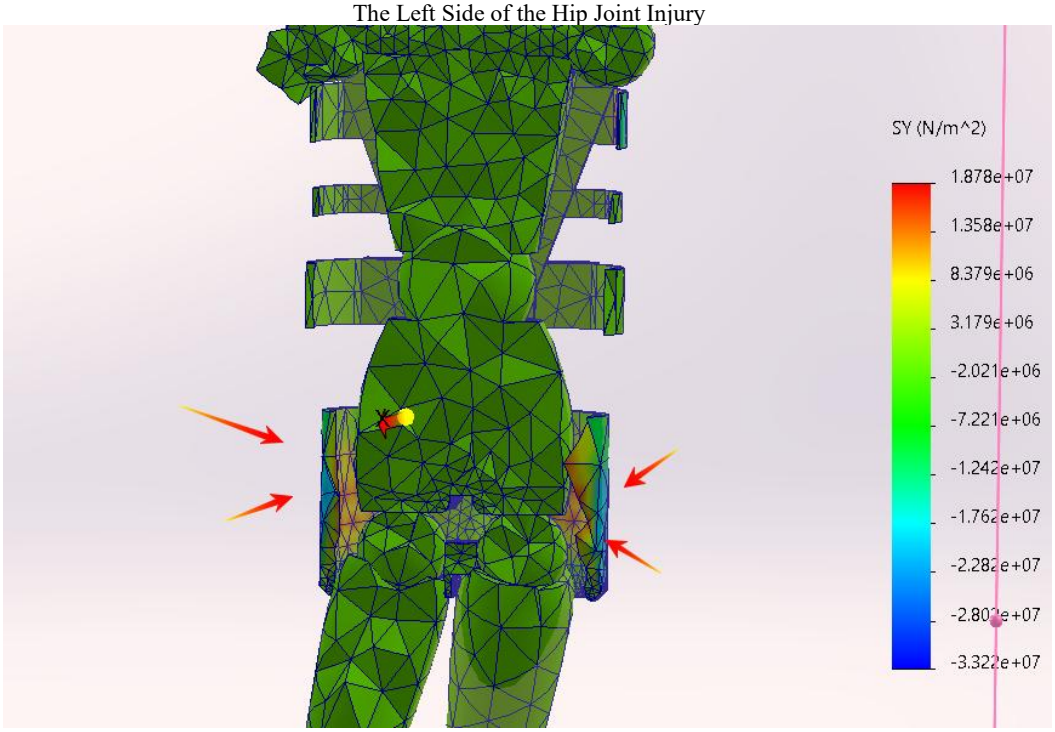
Table 4. Intervention Strategies of Photovoltaic Equipment on Competitive Injuries

Functional Interventions	Correspondence with Current and Voltage	Non-functional Interventions	Correspondence with Current and Voltage
Creatine kinase (CK) increased by 2SD within 3~4 weeks, and other indicators were in M±1SD	The current is: 0.3~0.4, and the voltage is 6.5~7V	There are 5 scenarios where the recovery time is more than 2 weeks: 1) CK increased by 2SD for 3 consecutive weeks, and Hb decreased by 2SD for 3 consecutive weeks; 2) Hemoglobin (Hb) and testosterone (T) decreased by 2SD for 3 consecutive weeks 3) CK and cortisol (C) increased by 2SD for 3 consecutive weeks; 4) Hb decreased by 2SD for 3 consecutive weeks, and C increased by 2SD for 3 consecutive weeks. 5) C decreased by 2SD for 3 consecutive weeks.	The current is: 0.35~0.45, and the voltage is 6.1~6.5V.
Intervention strategy load factor of photovoltaic equipment = 75.32.			

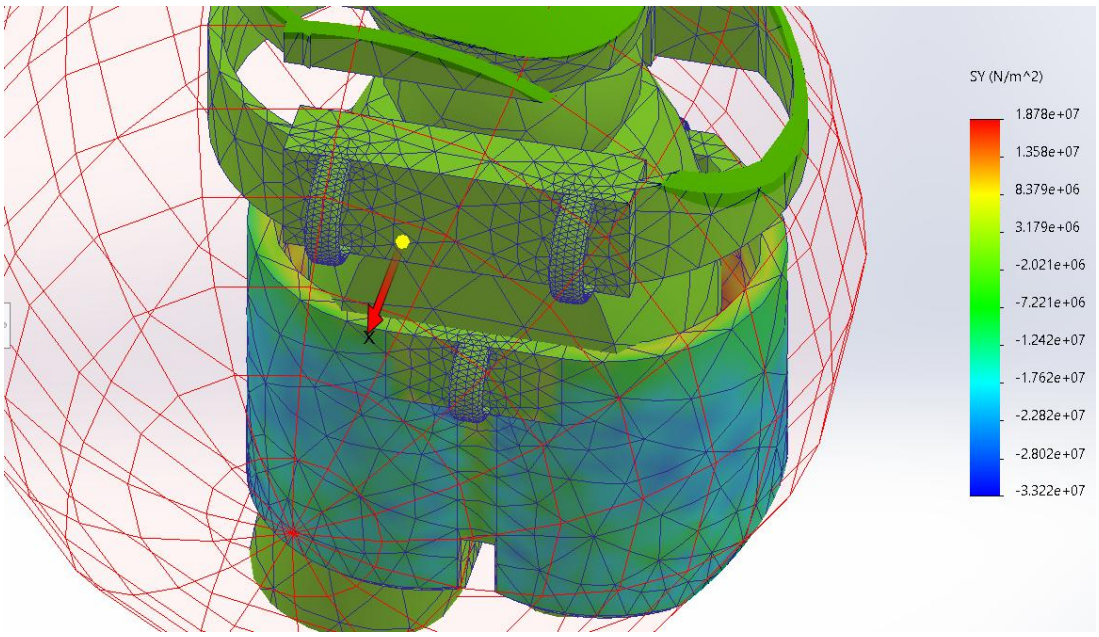
According to existing research, after an athlete is injured, there will be changes in hemoglobin, creatine kinase, testosterone, cortisol, amino acids, folic acid, ferritin, iron ions, and blood lactate. These include functional and non-functional interventions, which provide an important reference for the treatment of competitive injuries in volleyball players, and also provide recommendations on diet and weight based on the database. In addition, the early warning intervention of photovoltaic equipment for competitive injuries is not only based on the wide range of biochemical indicators but also based on the changes in the athlete's own biocurrent, as shown in the figure below.



The Left Side of the Hip Joint Injury



Anterior Aspect of Hip Joint Injury



Posterior Side of Hip Joint Injury

Figure 4. Early Warning Scanning of Human Bioelectricity by Photovoltaic Equipment

From Figure 4, it can be seen that the photovoltaic equipment can judge the physical changes of the athlete itself through the test of current, voltage and power flow, especially the abnormal information of bioelectricity, and form an economic damage report, and the results of the photovoltaic equipment scanning can be found to meet the actual test requirements by comparing the scanning structure diagram, which can provide support for further damage analysis and detection, and has the advantages of fast detection speed and low test cost, so the photovoltaic equipment can feed the athlete's competitive injury early warning, provide support, and realize the continuous test of human bioelectricity, and the current conversion rate of the photovoltaic equipment itself is 70% can achieve ultra-long standby to meet the needs of real-time monitoring of athletes.

4. Conclusion

Bioelectricity is a microelectric current produced by human cells during activities, which has the characteristic characteristics of obvious signal continuity and will fluctuate significantly when abnormal conditions occur in the body, such as joint damage, muscle strain, etc. Therefore, testing biopotential can predict injury in competitive athletes. In the monitoring process, there are problems such as short monitoring time and poor signal recognition, so this paper proposes a device based on photovoltaic energy to continuously monitor human bioelectricity, simplify the data through mathematical algorithms, connect with the health server, find the injury signal of athletes, and give early warning. The research results show that photovoltaic energy can identify the abnormalities of human bioelectricity through the changes of power flow, voltage and current, and judge the bioelectronic identification through the amplification function, with an accuracy rate of more than 75%. In addition, the complexity of the damage signal is reduced by the data function, and continuous detection can be carried out for 24 hours. During the test, it was found that the current and voltage of the photovoltaic equipment itself are relatively stable, which can be continuously monitored and provide a basis for clinical diagnosis. After biopotential testing, early warning interventions can be carried out based on the patient's own health database to help him treat the injury at the best time. Through computer simulation signal conversion, it can be found that photovoltaic equipment has a high recognition rate of about 60~70% for the scope and cause of damage. In the research process, this paper only analyzes photovoltaic equipment, and lacks massive data analysis of the actual situation of economic resource damage and its own causes, and will combine human bioelectric analysis with other wearable devices in the future to realize the multi-index judgment of economic damage and improve its accuracy.

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