Research Article

Photothermal Effect Based on Bionic Nanomaterials in the Treatment of Football Sports Injuries

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As more and more people love football and participate in more and more football matches, the physical injuries in the confrontation are getting more and more serious. In recent years, bionic photothermal nanomaterials have shown great application potential in disease treatment. Biomimetic photothermal nanomaterials are functional and intelligent materials with special excellent performance that are designed and synthesized by using natural biomimetic principles. Photothermal therapy (PTT) technology is a new treatment technology in recent years. On the one hand, photothermal therapy technology can convert light energy into heat energy through photothermal conversion factor (PTCA). Molecular water-soluble drugs penetrate into the skin to replace the existing injection administration methods with higher risk and low patient compliance and oral administration methods that generally cause first-pass effects, improve the utilization and efficiency of drugs, and can give provide patients with better treatment. The purpose of this article is to explore the application of the photothermal effect of bionic nanomaterials in the treatment of football sports injuries. The method adopted in this paper is to synthesize different bionic photothermal nanomaterials and synthesize bionic photothermal nanomaterials that are fused with cell membranes, thereby promoting the application of photothermal therapy technology in the treatment of sports injuries; further, by synthesizing bionics wrapped by fusion membranes, photothermal nanomaterials introduce collaborative photothermal therapy technology. The experimental results show that the photothermal effect of nanobiomimetic materials is used to treat common injuries caused by football sports. Compared with traditional treatment methods, HA-CuS gel and near-infrared treatment are applied to the skin with the injured tissue of the experimental group. It dropped to 85.7% in 2 h then gradually dropped to 84.2%, and the recovery speed was significantly accelerated.

1. Introduction

Football injuries refer to various physical injuries caused by athletes in football matches. Because football is more intense, and the physical quality and sports skills of athletes are high requirements, and football injuries often occur. In addition to common bruises and contusions, the most common injuries are ankle sprains, muscle tightness, and contusions on the front and back of the thigh, and knee injuries are the second most common [1]. Among them, meniscus inhabitation, knee ligament tears, bone fractures, and osteochondrosis are relatively rare, but once they occur, treatment is more difficult. It needs to rely on some advanced medical technology to treat football sports injuries. The key to photothermal treatment technology is photothermal conversion factor. At present, there are many types of photothermal conversion nanomaterials that have been studied most. The list is mainly divided into the following categories: high-cost photothermal conversion nanomaterials composed of precious metals and rare metals, new synthetic carbon based on light-to-heat conversion nanomaterials, old-fashioned organic compounds, light-to-heat conversion nanomaterials, and semiconductors composed of light and heat conversion nanomaterials [2, 3]. It has been shown that the abovementioned heat has poor biocompatibility to thermal nanomaterials and cannot escape from the human immune system, and no precise damage has been observed [4, 5].
Years of research and analysis on football sports injuries have shown that the incidence of sports injuries in regular college football teams is 211.9%, among which athletes’ injuries are mainly concentrated in the ankle joints of the feet, knee joints, thighs, calf muscles, and feet of the legs. Toes, hip joints, etc. and ankle sports injuries have the highest incidence; the results of sports injuries mainly include contusions, sprains, bruises, residual limbs, residual limbs, etc. The main reason for sports injuries is insufficient mastery of their skills. Even the lack of training level is mostly caused by human factors, including lack of scientific training and other objective factors. At the same time, it puts forward targeted suggestions to promote the improvement of skills and tactics in football team training in mainstream colleges and universities, prevents sports injuries, and provides useful help [6–8]. Studies have shown that football players’ injuries are mainly concentrated in the lower limbs, especially in the ankle. The main causes of injuries are improper technical exercises, protection errors, insufficient preparations, and other factors, as well as increased frequency of sports injuries, which should attract people’s attention. We propose appropriate preventive measures to further prevent and reduce sports injuries in future training and competitions [9]. In the past ten years, photothermal hyperthermia has become a new treatment technique. It uses the largest external energy to heat cells or tissues, degenerate and necrosis of cells or tissues, and then plays a role in repairing cells [10]. This method is usually a more moderate method, which is less harmful to the human body. The main sources of external energy for heating cells or tissues are radio frequency, microwave oven, focused ultrasound, and laser [11]. The normal cells or tissues of the human body emit heat when the temperature of the human body rises, accelerate blood flow, and expand blood vessels. Therefore, even if the temperature of the normal tissues or cells of the human body rises to 43°C, it will not cause great damage and can self-dissipate [12–14]. In necrosis, the new intercellular blood vessels are malformed and develop abnormally, their shape is abnormal, and the endothelial cells of the internal vascular endothelial cells are very fragile and easy to destroy. Therefore, the cells or tissues cannot dissipate heat normally and rise and cannot be adjusted and repaired. The cells are killed at high temperatures.

This article starts with the meaning of bionic nanomaterials and sports injuries and explores the relationship between the treatment effects of bionic materials based on the degree of injury. By establishing injury models, using biomimetic nanomaterials to observe different changes in cell, tissue and bone activity and conduct comparative studies, we can more accurately grasp the disease process and explore the impact of biomimetic nanomaterials on treatment. This is conducive to the promotion of medical research problems, innovative methods to solve problems, and a good theoretical basis for the treatment of football injuries and other diseases caused by them. By comparing the changes and analyzing the specific experimental results, we can find the basic point of balance between the body’s response and drug efficacy, and organically combine the two, provide valuable technical experience for future experiments, draw out the similarities and differences in research directions through comparative advantage analysis, and learn advanced experience at the same time, and make suggestions for improvements in future medical technology advancements, in-depth understanding of the body’s pathological conditions, and strengthening of medical expertise. Specialization and accuracy provide theoretical basis for the medical field.

2. Theoretical Basis and Method

2.1. Core Concepts

2.1.1. The Concept of Football Damage. According to foreign records, football is one of the sports with the highest injury rate [15]. Minor injuries are wear and tear, fractures, and dislocations, and ruptures of internal organs can be severe. According to the Guangdong Provincial Sports Commission Medical Bureau (classified by training effect), minor injuries accounted for 47.8%, moderate injuries accounted for 19%, and severe injuries accounted for only 3.2%. Approximately, 86% of injuries are limbs [16, 17]. In addition to common bruises and contusions, the most common injury is an ankle sprain. The muscles of the front and back of the thigh are tight and bruised. Knee injuries ranked second. Among them, meniscus habitation, knee ligament tears, bone fractures, and osteochondrosis are relatively rare, but if they occur, it is a bad news for athletes. The treatment methods are currently immature, and the effects of drug treatment are mediocre and difficult to cure, seriously affecting the sports career of football players and cause them great difficulties. For many professional football players, the meniscus or bone has been removed in some medically developed countries. Since goalkeepers often drop the ball and fall, they are vulnerable to wrist (scaphoid fracture) and elbow injuries (bursitis and hematoma). Therefore, the average goalkeeper must wear a sweater, elbow pads, and gloves [18, 19].

2.1.2. Photothermal Treatment. Photothermal therapy is a medical technique for minimally invasive treatment using photoseal developed in recent years. This technology uses photothermal modified materials to directly increase the local temperature by directly irradiating the site with light, thereby killing cells and significantly reducing the body’s systemic toxicity. Therefore, photothermal therapy is one of the therapeutic techniques that have the potential to replace surgical therapy. The light-to-heat conversion material can convert the energy of the laser into heat, thereby generating high temperature in the cell area of the human body. The high temperature will heat the cell structure and cause the cell to die quickly. Near-infrared lasers, whose main wavelength range is from 700 to 1100 nm, have a very strong ability to penetrate biological tissues for human or animal tissues and have very little residue in the body after passing through the human body. It can be widely used in the treatment of sports injuries and has become one of the important light sources widely used in the medical field [20, 21]. In order to promote the application of photothermal therapy technology, the development of photothermal...
conversion nanomaterials with good biocompatibility and high conversion efficiency is the current focus of photothermal therapy. Nanomaterials with a particle size in the range of 10-200 nm can avoid the body kidney and cam clearly and selectively penetrate into the tissue. The use of nanophotothermal rice materials for photothermal therapy is an effective method [22].

2.2. Light-to-Heat Conversion Nanomaterials

2.2.1. Introduction to Nanomaterials. Currently, the most studied photothermal conversion nanomaterials include noble metal photothermal conversion nanomaterials, carbon-based photothermal conversion nanomaterials, organic compounds photothermal conversion nanomaterials, and semiconductor photothermal conversion nanomaterials. The carbide nanomaterials that convert from heat to heat mainly include gold nanostructures and palladium nanostructures [23]. The photothermal conversion characteristics of precious metals are produced by the plasmon resonance effect of nanoparticles on the surface, which is directly related to the morphology of precious metal nanostructures: gold nanorods, gold nanometer dials, gold nanoparticles, etc. However, as the temperature increases, the photothermal conversion nanomaterials of precious metals will undergo morphological changes, resulting in unstable light and thermal conversion properties, which limits the widespread use of precious metals as photothermal conversion materials in disease treatment [24].

2.2.2. Specific Realization Form. Carbon-based nanomaterials for light and heat conversion mainly include graphene structures and carbon nanotubes. In principle, it does not affect the photothermal conversion characteristics of carbon-based photothermal conversion nanomaterials after long-term laser irradiation, but the preparation and functionalization of carbon-based photothermal conversion nanomaterials are complex, and their light absorption coefficient is relatively low. The photothermal conversion nanomaterials mainly include organic infrared dyes, porphyrin liposomes, and high molecular polymers [25]. Compared with other types of light and heat conversion nanomaterials, this type of tube property conversion nanomaterials can be biodegraded, but they are easily directly degraded by light under long-term laser irradiation. As a research hotspot of nanomedicine, copper sulfide (CuS) nanoparticles in semiconductor photothermal conversion nanomaterials have the advantages of simple preparation process, stable photothermal conversion performance, excellent biocompatibility, and low production cost [26].

2.2.3. Application of Photothermal Nanomaterials. The key points in treatment are issues such as immune system escape and precise targeting to reach the site. Under normal circumstances, our tissues have permeation and retention effects (EPR), and humans use these two effects to design photothermal nanomaterials and guide them to the passive targeting of markers. One of the most important issues is how to extend the residence time of nano-biomimetic materials in organisms. In order to extend the residence time of photothermal materials in organisms, polyethylene glycol is often used to modify the materials, and this method can be used to a certain extent, increase the hydrophilicity of the surface of nanomaterials, reduce the elimination of imitation biomass by the immune system when inside the body, and reduce the interaction between nanomaterials and components in the blood, thereby avoiding attack and elimination by the body’s immune system [27, 28]. In order to improve the targeting ability of nanomaterials, active molecules, such as aptamers and penetrating peptides, can be modified on the surface of nanomaterials. Recent studies have shown that there is an antipolyethylene glycol immune response in animals and humans. Polyethylene glycol can cause blood clotting and cell coagulation. To a certain extent, it cannot completely prevent nanomaterials from being processed by the machine. In efficacy, while a single targeted modified nanomaterial is difficult to adapt to the microenvironment in the body, it is difficult to achieve its theoretical targeting effect after entering the body. In recent years, effective methods have used cell membranes to camouflage the upper layer of nanomaterials and modify the nanomaterials to obtain bionic nanomaterials that have the ability to escape the immune system. Biomimetic nanomaterials have good development prospects in drug transportation, imaging, detoxification, vaccine design, and photothermal therapy. The cell membrane wrapped nanomaterial mainly includes two parts: a synthetic nanomaterial core and an outer cell membrane. The core synthesized in the biomimetic nanomaterial can be organic or inorganic nanomaterials with different biological and therapeutic functions. The outer cell membrane used to camouflage the nanomaterial nucleus can be red blood cell membrane, white blood cell membrane, cancer cell membrane, platelet membrane, macrophage membrane, and fusion membrane.

3. Experimental Verification

3.1. Experimental Materials. Through the application, 60 people with sports injuries in the affiliated hospital of the medical university where the author is located were selected, including 30 men and 30 women. In order to create research variables, all patients were randomly divided into 6 groups with 10 people in each group to ensure that the weight of the patients was normal. In the early stage of the experiment, in a well-ventilated environment, ensure that the room temperature is about 22 degrees, the relative humidity is maintained at about 55%, and the light time is maintained at more than 10 hours. Keep adequate food and drinking water. Conventional catering is provided by the medical center, and the MCT required for the establishment of the entire model is selected from sigma. When each group is treated to the appropriate age, the injured tissue should be selected for observation of related indicators. The main reagents include ECL chemiluminescence fluid (Genview company in the United States), and the main instruments include color Doppler ultrasound diagnostic apparatus, optical microscope (Germany LEICA, DM3000).
3.2. Experimental Process. First, complete the preparation of HA-CuS nanoparticles. 150 mg of HA was added to 20 mL of 4 mL CuCb solution, after stirring for 30 min at room temperature, and 1.6 mL of 50 mM Na2S solution and 36 mg of trisodium citrate were added to the system. After stirring quickly, let it stand and heat in a water bath at 80 °C for 30 minutes. Centrifuge at 12000 rpm for 30 minutes, discard the supernatant, add deionized water to the sedimentation towel, and resuspend at 12000 rpm for 30 minutes, repeat twice to obtain HA-CuS nanoparticles. The synthesis process of the blank CuS nanoparticles is the same as the above steps, but HA is not added. HA is an acidic mucopolysaccharide. During the synthesis of HA-CuS nanoparticles, it needs to be heated in a water bath at 80 °C for 30 minutes. In order to explore whether the treatment will affect the structure of HA, gel permeation chromatography (GPC) is used in this chapter. The molecular weight distribution of HA is tested. Use two detectors: laser light scattering detector and differential detector to detect the molecular weight distribution of HA before and after heating. The molecular weight of HA will not be affected by the heating during the synthesis process and remains stable, which provides conditions for the successful synthesis of HA-CuS. The laser light scattering detector detects the molecular weight distribution of HA before and after heating as shown in Table 1. The GPC curve of molecular position distribution before and after HA heating detected by the differential detector is shown in Table 2.

Table 1: Laser light scattering detector detects the molecular weight distribution of HA before and after heating.

<table>
<thead>
<tr>
<th>Time</th>
<th>Before heating(mV)</th>
<th>After heating(mV)</th>
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<tbody>
<tr>
<td>5 min</td>
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<tr>
<td>45 min</td>
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<td>9</td>
</tr>
<tr>
<td>50 min</td>
<td>7</td>
<td>6</td>
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Table 2: GPC curve of molecular position distribution before and after HA heating detected by differential detector.

<table>
<thead>
<tr>
<th>Time</th>
<th>Before heating(mV)</th>
<th>After heating(mV)</th>
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<tbody>
<tr>
<td>5 min</td>
<td>0.69</td>
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<tr>
<td>10 min</td>
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<td>20 min</td>
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<td>25 min</td>
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<td>30 min</td>
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<td>35 min</td>
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<td>40 min</td>
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<td>45 min</td>
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<tr>
<td>50 min</td>
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<td>0.68</td>
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</table>

Stain the RBC membrane with DIL staining solution, and stain the B16F10 cell membrane with DIO staining solution. According to the ratio of B16F10 cell membrane to RBC membrane mass ratio of 1:1, mix the B16F10 cell membrane with the RBC membrane uniformly and ultrasound at 39°C for 10 minutes to complete the cell membrane fusion. 0.5 mL of 0.3 mg/mL B16F10 membrane solution was added to 0.5 mL of 0.2 mg/mL CuS nanoparticle solution, and the membrane was wrapped by ultrasound for 10 min at room temperature. The reaction system was centrifuged at 10,000 rpm for 5 minutes at 4°C to remove excess membrane. The precipitate is CuS@B16F10 nanoparticles and

The MTT method for detecting the cytotoxicity of HA-CuS under near-infrared light irradiation and the variation curves of HA-CuS nanoparticle solutions with different concentrations are shown in Figures 1 and 2, respectively.
resuspended in FJ deionized water. Similarly, complete the RBC film alone package and B16F10 film alone package. Thus, CuS@RBC nanoparticles and CuS@R16 nanoparticles were obtained.

3.3. Experimental Results. HA is a very promising mucopolysaccharide that mediates transdermal administration and has excellent biocompatibility. The modification of CuS nanoparticles with HA has an important effect on improving its biological toxicity. Before using HA-CuS nanoparticles for biological applications or disease treatment, it is necessary to detect their cytotoxicity. In this chapter, the MTT method is used to detect the cytotoxicity of HA-CuS nanoparticles using NHDF cells. Transfect NHDF cells with a series of sample solutions of different concentrations (200 pg/mL, 100 pg/mL, 50 pg/mL, 25 pg/mL, and 10Hg/mL) and use MTT to detect cell viability even at a high concentration of 200 ng/mL under the condition of sample treatment, the survival rate of cells is also above 90%, indicating that HA-CuS nanoparticles have no direct cytotoxicity.

4. Data Analysis

HA-CuS gel-mediated transdermal drug delivery is realized under the irradiation of near-infrared light. Before the biological application of HA-CuS gel-mediated transdermal drug delivery in animal experiments, near-infrared light must be performed in stimulated HA-CuS cellularity test. A high-power 980 nm near-infrared laser (0.58 W/cm²) was used to irradiate the HA-CuS-intaken NHDF cells and normal NHDF cells for 30 s and 10 min. The results are shown in Figure 1. Normal NHDF cells had a cell survival rate of 91.1% after 10 minutes of near-infrared laser irradiation, while NHDF cells that had taken HA-CuS had a cell viability rate of 89.1% after 30 s of near-infrared light irradiation, and the time was extended to 10 minutes. The cell survival rate is only 57.6%. The experimental results show that HA-CuS has lower cytotoxicity when the near-infrared light is stimulated for a short time, and when the near-infrared light stimulation time is increased to 10 min, HA-CuS has a higher photothermal conversion property. Therefore, when HA-CuS gel-mediated transdermal administration is performed, the irradiation time of near-infrared light must be controlled.

The concentration of HA-CuS nanoparticle solution is an important factor affecting its photothermal conversion. We have prepared a series of HA-CuS nanoparticle solutions with different concentrations (1000 pg/mL, 500 pg/mL, 100 pg/mL, 50 pg/mL, and 25 pg/mL) to examine its light-to-heat conversion capability. We use a 980 nm near-infrared light source, adjust the intensity to 0.7 W/cm², irradiate the solution for 600 s, and record the temperature every 2 s, so as to obtain the temperature change curve of HA-CuS nanoparticle solutions with different concentrations as shown in Figure 2.

First, we conducted a temperature increase test on deionized water for damaged tissue cells. Within 600 s, the temperature of deionized water only increased by 13°C, while the h-rise temperature of the HA-CuS nanoparticle solution without concentration was 18.4°C, (25 pg/mL), 26.3°C (500 pg/mL), 32.7°C (100 pg/mL), 39.7°C (500 pg/mL), and 43.4°C(400pg/mL). This result shows that HA-CuS nanoparticle solution has strong light-to-heat conversion capability. In addition, with the increase of time, the heating efficiency of the HA-CuS nanoparticle solution continues to weaken. This is because as the temperature increases, the heat loss of the solution increases, and the material can quickly convert the near-infrared light energy.
into heat energy, and five is released into the aqueous solution and the surrounding environment, which also shows from the side that HA-CuS nanoparticles have good light-to-heat conversion ability. As the concentration of the HA-CuS nanoparticle solution increased, the material did not undergo coagulation. This is because the HA-CuS nanoparticle played a protective role and made the CuS nanoparticle uniform and stable at a higher concentration. At the same time, we further tested the stability of the photothermal conversion of HA-CuS nanoparticles. We took the highest concentration of HA-CuS nanoparticles solution (1000 pg/mL) in the above series of solutions for 5 times of excitation for 600 s. Cooling hot and cold cycle. The results are shown in Figure 3. The highest peaks of the solution temperature are 69.4°C, 69.3°C, 69.1°C, 69.3°C, and 69.2°C. The slight temperature peak changes indicate that HA-CuS nanoparticles have stable and repeatable light thermal conversion capability.

We use exercise-impaired patients as disease models to study the feasibility of the biological application of HA-CuS gel-mediated transdermal drug delivery. After applying HA-CuS gel on the back of the patients in the experimental group, they were blown dry with a hair dryer, then the gel-treated skin was irradiated with near-infrared light, the gel was wiped off, and the insulin-containing patch was applied to the treated skin with continuous absorption of the drug. The patients in the control group directly attached patches with insulin, directly injected insulin subcutaneously and did not undergo any treatment. Use a blood glucose meter to monitor blood glucose changes every 2 hours until 10 hours. The experimental results of each group are compared as shown in Figure 4. The blood sugar of the control group patients without any treatment and the control group patients who directly applied the patch without skin treatment has been at a high level; the skin is treated with HA-CuS gel and near infrared and then the insulin patch is applied. The blood glucose of the experimental group of patients dropped to 85.7% at the 2nd hour, then gradually dropped to 84.2%, and finally rose to 99.6% at the 10th hour; the blood glucose level of the control group who received direct subcutaneous insulin injection dropped rapidly to 52.7% at the 2nd hour. After that, it rose rapidly, and the blood glucose levels at 6h, 8h, and 10h were 93.1%, 97.1%, and 105.7%. The above experimental results show that the transdermal insulin infusion mediated by HA-CuS gel can stabilize the blood glucose level at a lower level for a longer period of time than the conventional subcutaneous insulin injection, providing a stable and effective treatment for the treatment of sports injuries.

5. Conclusion

The photothermal effect of HA-CuS nanoparticles is used to thermally ablate the skin, mediating a new way of transdermal drug delivery. HA-CuS nanoparticles have good biocompatibility and light-to-heat conversion properties. Under low-intensity near-infrared light irradiation, HA-CuS gel is sufficient to cause damage to the stratum corneum without damaging the deeper skin and can effectively make BSA penetrate into the skin. Taking type I injury as the disease model and insulin as the water-soluble macromolecular drug model, the transdermal drug delivery method mediated by HA-CuS gel can keep the patient’s blood sugar at a stable low level for a long time. The transdermal drug delivery method based on the photothermal effect of HA-CuS nanoparticles has great prospects in future clinical applications because of its superior biocompatibility and controllable and stable therapeutic effect.

Use HPDA@[OMV-CC] nanoparticles to perform photothermal therapy and immunotherapy on the injured site. HPDA@[OMV-CC] nanoparticles have good biocompatibility; HPDA@[OMV-CC] nanoparticles have good light-to-heat conversion properties at 1064 nm; HPDA@[OMV-CC] nanoparticles have the same targeting properties. The ability to source damaged tissues can effectively restore damaged cells under near-infrared light; HPDA@[OMV-CC] nanoparticles can increase the amount of dendritic cells entering the lymph nodes and promote the maturation of dendritic cells. In future research, the ability of HPDA@[OMV-CC] nanoparticles’ photothermal therapy and immunotherapy for sports injuries can be studied in vivo and further biosafety studies. On the basis of existing research, the ability to increase immunotherapy by fusing bacterial outer membrane vesicles provides a new direction for the application of biomimetic photothermal nanomaterials in the treatment of sports injuries.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References


