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Bone and Arthroscopy Science

Focus and Scope

Bone and Arthroscopy Science is a peer-reviewed articles across a wide spectrum of clinical treatise, basic research, review, frontier of orthopedics, case analysis and comment. This journal is aimed at professionals at all levels engaged in the basic and clinical work of orthopedics. Each issue is guest-edited by an acknowledged expert and focuses on a single topic or controversy.

It mainly reports new viewpoints, new achievements and new technologies in basic and clinical research of bone and joint surgery. The covered topics include, but are not limited to: sports medicine and arthroscopy, prosthetic design, biomechanics, biomaterials, metallurgy, biologic response to arthroplasty materials *in vivo* and *in vitro*.

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Hemostatic Effects of Tranexamic Acid on Geriatric Total Hip Arthroplasty

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Abstract: *Objective:* The aim of this paper was to investigate the hemostatic effect of tranexamic acid in elderly patients undergoing artificial hip arthroplasty. *Methods:* Ninety-six patients who underwent artificial hip replacement surgery from June 2023 to January 2025 were selected and divided into two groups of 48 cases each. Tranexamic acid was applied intraoperatively in the observation group, and hemostasis was performed by conventional methods in the control group. Intraoperative bleeding, postoperative bleeding, total blood loss, proportion of blood transfusion, hemoglobin, erythrocyte pressure volume, and other complications were compared between the two groups. *Results:* The intraoperative bleeding volume, postoperative drainage volume, and total blood loss in the observation group were significantly lower than those in the control group ($P < 0.05$), and the transfusion rate was also significantly lower than that in the control group ($P < 0.05$). Postoperatively, hemoglobin and erythrocyte pressure volume decreased less in the observation group than in the control group ($P < 0.05$). There was no significant difference in the complication rate between the two groups ($P > 0.05$). *Conclusion:* Tranexamic acid applied to hip arthroplasty in the elderly can effectively reduce intraoperative and postoperative bleeding, reduce the rate of blood transfusion, and does not increase the risk of complications, and has clinical promotion and application values.

Keywords: Elderly; Hip arthroplasty; Tranexamic acid; Hemostatic effect

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1. Introduction

Hip arthroplasty is an important medical tool to treat hip diseases in the elderly, and it is effective in improving the joint function and quality of life of patients ^[1-3]. With the deepening of social aging, the number of elderly hip disease patients continues to rise, making the application of hip arthroplasty more and more common ^[4-6]. For example, femoral neck fracture is a common condition because the bones of the elderly are relatively loose, and the slightest external force can cause a fracture ^[7]; femoral head necrosis as well as osteoarthritis of the hip

joint also have a higher incidence in the elderly population ^[8,9]. These diseases greatly limit the patient's ability to perform daily activities, and in severe cases, patients may be bedridden for a long period of time, which may lead to a series of complications.

However, one of the prominent challenges of hip arthroplasty is intraoperative and postoperative bleeding ^[10,11]. Relevant studies ^[12] have shown that the hemophilia of elderly patients can reach 1500–2000 ml, and the transfusion rate is more than 68%. Elderly patients' body functions decline, cardiopulmonary function reserves are insufficient, and large blood loss will not only cause anemia, affecting the normal functioning of the body organs, but also may lead to reduced patient immunity, increasing the risk of infection ^[13]. Although blood transfusion can replenish blood volume, the adverse reactions that blood transfusion may bring, such as infection, allergic reaction, transfusion-associated acute lung injury, etc., add additional risks to patients, and in serious cases, may even be life-threatening ^[14,15]. In addition, bleeding and blood transfusion can prolong the patient's hospital stay and increase healthcare costs, causing a significant economic burden on the patient's family and society.

Tranexamic acid is a class of compounds with strong antifibrinolytic activity, which can prevent the degradation of fibrinogen by competitively blocking its binding to fibrin, and plays a role in hemostasis ^[16-18]. In recent years, the application of tranexamic acid in orthopedic surgery has gradually increased, and its safety and efficacy have been verified to a certain extent ^[19,20]. However, there is a lack of in-depth research on the optimal use regimen of tranexamic acid for the specific group of elderly hip arthroplasty and its effect on the long-term prognosis of patients. Therefore, an in-depth discussion of the hemostatic effect and safety of tranexamic acid in elderly hip arthroplasty is of great practical significance for optimizing clinical treatment protocols and improving patient prognosis.

2. Materials and methods

2.1. Case selection

Elderly patients who underwent hip arthroplasty in our Orthopedic Department from June 2023 to January 2025 were selected. The inclusion criteria were: (1) Age 60 years and above; (2) Confirmed diagnosis of osteonecrosis of the femoral head, fracture of the femoral neck, or osteoarthritis of the hip and the need for hip arthroplasty; (3) American Society of Anesthesiologists (ASA) grade I to III; and (4) Informed consent signed by the patient or family. Exclusion criteria included: (1) Allergy to tranexamic acid; (2) Coagulation disorders or hematological disorders; (3) Recent use of anticoagulant or antiplatelet drugs; (4) Severe hepatic and renal insufficiency; and (5) A combination of other serious medical illnesses that could not tolerate the surgery.

2.2. Grouping method

Using the random number table method, 96 patients were divided into two groups, with 48 cases in each group. The data of the two groups of patients in terms of general information were comparable, $P > 0.05$, the specific data are shown in **Table 1**.

Table 1. Comparison of general information of patients in two groups

Info		Observation group (<i>n</i> = 48)	Control group (<i>n</i> = 48)	<i>t/χ²</i>	<i>P</i>
Gender	Male	26	25	0.042	0.838
	Female	22	23		
Age		68.47 ± 5.34	67.96 ± 6.18	0.433	0.666
BMI (kg/m ²)		23.39 ± 3.62	23.68 ± 3.17	0.418	0.677
Disease type	Femoral head necrosis	19	16	0.405	0.525
	Femoral neck fracture	15	17	0.188	0.665
	Hip osteoarthritis	14	15	0.049	0.824
ASA	I	11	9	0.253	0.615
	II	27	30	0.389	0.533
	III	10	11	0.061	0.805

2.3. Treatment methods

Surgical method: In this study, hip arthroplasty in both groups was performed by the same surgical team to ensure the consistency and stability of the surgical operation. The specific operations are as follows: (1) General anesthesia; (2) Posterior lateral approach: With the patient in the supine position, incision was made from the posterior side of the hip, the skin, subcutaneous tissue, and deep fascia were incised sequentially, the greater trochanter was separated, the external rotator muscle group was exposed and the attachment point of the external rotator muscle group was pulled inward, exposing the hip capsule; (3) Joint dislocation and exposure: The joint capsule was incised and the head of the femur and the acetabulum were exposed. The hip joint was dislocated by manipulation or instruments to better expose the surgical field and facilitate subsequent operations; (4) Femoral side preparation: The femoral head was removed, the medulla was expanded using a medullary file, the appropriate type of femoral prosthesis was selected according to the patient's bone condition and implanted into the femoral medullary cavity, ensuring that the position of the prosthesis was appropriate and securely fixed; (5) Acetabular side preparation: An acetabular file was used to grind the acetabulum so as to match with the acetabular prosthesis; a suitable acetabular prosthesis was chosen to be implanted into the acetabulum, usually using cemented or non-cemented fixation to ensure that the acetabular prosthesis was stable; (6) Prosthesis installation and reset: The femoral head prosthesis was installed on the femoral stem, and then the hip joint was reset to check whether the joint mobility, stability, and position of the prosthesis were good.

Hemostatic method: (1) The control group adopted the conventional hemostatic method; during the operation, the surgical team carefully and meticulously performed a hemostatic operation on the surgical wound to reduce intraoperative bleeding as much as possible. After completing the hip replacement surgery, a drainage tube was placed at the incision in order to drain out the blood and fluid seepage from the postoperative wound and prevent the accumulation of blood and fluid from causing infection or other complications. (2) In the observation group, the application of tranexamic acid was added on the basis of conventional hemostasis. Specifically, tranexamic acid was given to patients by intravenous drip at a dose of 15 mg/kg 10 minutes before skin incision, so that the drug entered the patient's body in advance to exert its hemostatic effect. When the surgery was carried out before closing the incision, 1 g tranexamic acid was diluted in 200 ml saline and the wound was locally irrigated so that tranexamic acid could act directly on the surgical wound, and then the irrigating fluid was retained in the joint

cavity without suction in order to continuously exert the local hemostatic effect. Postoperatively, a drain was also placed at the incision site. The entire surgical process strictly followed the principle of aseptic operation, and the surgical team worked closely together to ensure the successful completion of the surgery.

2.4. Observation indicators

- (1) We recorded the intraoperative bleeding volume (estimated by the volume of blood in the suction bottle and the volume of blood absorbed by gauze), the postoperative drainage volume (24-hour postoperative drainage volume), and the total blood loss of both groups [calculated according to Gross' equation: total blood loss = preoperative blood volume \times (preoperative erythrocyte pressure volume – postoperative erythrocyte pressure volume)/preoperative erythrocyte pressure volume + postoperative drainage volume, wherein the preoperative blood volume is estimated according to the patient's body weight and gender].
- (2) The blood transfusion rate of patients in the two groups was counted, and the criteria for blood transfusion were set as postoperative hemoglobin < 70g/L or patients with obvious anemia symptoms.
- (3) Blood routine indexes: Patients' venous blood was collected before the operation, on the 1st postoperative day, and on the 3rd postoperative day, respectively, and the levels of hemoglobin and erythrocyte pressure volume were measured.
- (4) Complications: We observed and recorded the occurrence of postoperative complications in the two groups of patients, such as incision infection, deep vein thrombosis, pulmonary embolism, and so on.

2.5. Statistical methods

The data obtained were statistically analyzed by SPSS22.0 software, the count data were recorded as the number of cases and percentage, and analyzed by the method of χ^2 test, the measurement data were recorded as the mean and standard deviation (SD), and analyzed by the method of *t*-test, and the difference existed at the statistical level when $P < 0.05$.

3. Results

3.1. Comparison of blood loss and blood transfusion rate

The intraoperative bleeding volume, drainage volume, and total blood loss of patients in the observation group were significantly less than those of the control group, $P < 0.05$. The blood transfusion rate of the observation group was lower than that of the control group, $P < 0.05$, and the detailed data are shown in **Table 2**.

Table 2. Comparison of bleeding volume and blood transfusion rate between the two groups (mean \pm SD)

Groups	<i>n</i>	Intraoperative hemorrhage (ml)	Postoperative drainage (ml)	Total blood loss (ml)	Transfusion rate (%)
Observation group	48	325.49 \pm 80.27	207.13 \pm 50.41	852.46 \pm 159.74	10.42 (4/48)
Control group	48	467.54 \pm 101.23	314.67 \pm 69.87	1101.58 \pm 204.76	25.00 (12/48)
<i>t</i> / χ^2		7.618	8.648	6.646	7.293
<i>P</i>		0.000	0.000	0.000	0.007

3.2. Changes in hemoglobin and erythrocyte pressure volume

Comparison of hemoglobin and erythrocyte pressure volume levels between the two groups of patients before the operation was not significant, $P > 0.05$. On the 1st and 3rd day after the operation, hemoglobin and erythrocyte pressure volume decreased in both groups, but the decrease in the observation group was smaller than that in the control group, $P < 0.05$, the specific data are shown in **Table 3**.

Table 3. Comparison of changes in hemoglobin and erythrocyte pressure area between the two groups (mean \pm SD)

Groups	<i>n</i>	Time	Hemoglobin (g/L)	Erythrocyte pressure (%)
Observation group	48	Preoperative	130.5 \pm 10.2*	38.5 \pm 3.0*
		1 day after surgery	105.6 \pm 8.5 ^{#Δ}	32.0 \pm 2.5 ^{#Δ}
		3 days after surgery	100.8 \pm 7.8 ^{#Δ}	30.5 \pm 2.0 ^{#Δ}
Control group	48	Preoperative	131.2 \pm 10.5	38.8 \pm 3.2
		1 day after surgery	92.5 \pm 9.0 ^{Δ}	28.5 \pm 2.8 ^{Δ}
		3 days after surgery	88.0 \pm 8.2 ^{Δ}	26.8 \pm 2.2 ^{Δ}

Note: Compared with the control group before surgery, * $P > 0.05$; compared with the control group at 1 and 3 days after surgery, [#] $P < 0.05$; compared with the preoperative period, ^{Δ} $P < 0.05$.

3.3. Incidence of complications

Comparison of the complication rates of the two groups was not significant, $P > 0.05$ (**Table 4**).

Table 4. The occurrence of complications in the two groups [*n* (%)]

Groups	<i>n</i>	Incision infection	Deep vein thrombosis	Pulmonary embolism	Overall incidence
Observation group	48	1 (2.08)	1 (2.08)	0 (0.00)	2 (4.17)
Control group	48	2 (4.17)	2 (4.17)	1 (2.08)	5 (10.42)
<i>t</i>					1.387
<i>P</i>					0.239

4. Discussion

The results of this study clearly demonstrate the significant advantages of tranexamic acid in geriatric hip arthroplasty. After the application of tranexamic acid in the observation group, intraoperative bleeding, postoperative drainage, and total blood loss were significantly less than those in the control group, which directly indicates that tranexamic acid can effectively reduce surgery-related blood loss. The combination of intravenous drip before skin incision and topical application before closure of the incision played a hemostatic role from the beginning to the end of the surgery, effectively controlling the bleeding. The significant reduction in the transfusion rate not only reduces the risks of infection and allergy that may be associated with blood transfusion, but also lowers medical costs and the financial burden on patients.

In terms of changes in hemoglobin and erythrocyte pressure volume, the postoperative decrease in the observation group was smaller than that in the control group, which indicates that the use of tranexamic acid

helps to maintain the stability of the patient's blood indexes in the postoperative period, promoting the patient's postoperative recovery. Good blood indexes play a key role in the recovery of the normal function of various organs, and can effectively reduce dizziness, fatigue, and other uncomfortable symptoms caused by anemia, thereby enhancing the quality of life of the patient.

In terms of complications, although there was no significant difference in the complication rate between the two groups, there were cases of pulmonary embolism in the control group, while no serious thrombosis-related complications occurred in the observation group, which suggests that tranexamic acid does not increase the risk of thrombosis and has a high degree of safety when used appropriately. This may be due to the fact that tranexamic acid mainly acts on the local fibrinolytic system and has less effect on systemic coagulation.

However, this study has some limitations. The relatively small sample size may not fully reflect the differences in response to tranexamic acid in different individuals. The short follow-up period makes it difficult to assess the effect of tranexamic acid on the long-term prognosis of patients, aspects such as the long-term joint function recovery and periprosthetic osteolysis are still unclear. Future multicenter studies with larger scale and longer follow-up time are needed to further clarify the optimal use of tranexamic acid in geriatric hip arthroplasty and its effect on the long-term prognosis of patients.

5. Conclusion

Tranexamic acid used in geriatric hip arthroplasty can effectively reduce intraoperative and postoperative bleeding, lower the blood transfusion rate, improve the postoperative hemoglobin and erythrocyte product levels, and will not increase the risk of complications, which is conducive to patient recovery and is worthy of promotion and application in the clinic. However, in the process of application, it is still necessary to pay close attention to the patients' coagulation function and the occurrence of complications to ensure the safety and effectiveness of treatment.

Disclosure statement

The authors declare no conflict of interest.

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Exploration of the Value of Extract of Wuwei Xiaodu Drink on Rabbit Model of Spinal Infection

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Abstract: *Objective:* To study the therapeutic effect of the Extract of Wuwei Xiaodu Drink on spinal infection and provide the scientific basis for clinical application. *Methods:* By establishing a rabbit model of spinal infection, this paper observed and analyzed the changes in body mass before and after the intervention and the comparison of inflammation-related factors and blood leukocyte counts among the three groups. *Results:* There was a significant difference in the changes in body mass of rabbits before and after intervention in the experimental group, control group and blank group ($P < 0.05$); there was no statistically significant difference in calcitoninogen, C-reactive protein and routine blood leukocyte counts between the experimental group and the control group ($P > 0.05$), and there was a statistically significant difference in calcitoninogen, C-reactive protein and routine blood leukocyte counts between the experimental group and the blank group ($P < 0.05$). *Conclusion:* The Extract of Wuwei Xiaodu Drink can play a protective role by regulating the level of inflammatory factors in blood routine leukocyte count and reducing the inflammatory reaction in the spinal cord injury area.

Keywords: Extract of Wuwei Xiaodu Drink; Spinal infection; Rabbit model

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1. Introduction

The spine, as the central axis structure of the human body, is mainly composed of vertebrae, intervertebral discs and ligaments. In daily life, various factors may lead to spinal infections, such as trauma and bacterial infections. If left untreated, it may cause nerve damage and even affect the patient's life. Therefore, it is of great significance to study the prevention and treatment effects of spinal infections. In recent years, with the deepening of medical research, traditional Chinese medicine (TCM) has shown good therapeutic prospects in the prevention and treatment of spinal infections. Chinese medicine has multi-target and multi-pathway action characteristics and can play an immunomodulatory role by inhibiting the expression of inflammatory cytokines^[1]. Extract of Wuwei Xiaodu Drink is a recipe archived in "Pharmacopoeia of the People's Republic of China (2015 edition)." The main ingredients are honeysuckle, wild chrysanthemum, dandelion, *Viola philippica*, *Begonia fimbripetala*, etc., which

has the efficacy of clearing away heat and detoxicating, dispelling dampness and relieving pain, improving the “Qi” and strengthening the spleen, with astringent effect^[2]. This study conducted a preliminary study on Wuwei Xiaodu Drink in the previous period and found that the formula could effectively reduce the peripheral blood leukocyte count, abdominal macrophage phagocytic index, and serum total protein concentration of rabbits and reduce the peripheral inflammatory response, besides improving the liver index and increase the spleen index of rabbits, and exerted a better anti-inflammatory effect. In this study, the rabbit was used as an animal model, and a spinal infection model was established. By observing and analyzing the changes in body mass before and after the intervention of the three groups and the post-intervention inflammation-related factors and blood leukocyte counts, this study explored the interventional effects of the Extract of Wuwei Xiaodu Drink on spinal infection and its mechanism, to provide the scientific basis for the clinical application.

2. Materials and methods

2.1. General materials

2.1.1. Drugs and reagents

Ninety wild-grade SD rabbits, 8 weeks old, were selected. They were kept in an SPF animal house with free feeding and drinking water, and the room temperature was 25.00 ± 0.33 °C. Extract of Wuwei Xiaodu Drink was prepared by the School of Pharmaceutical Engineering of Traditional Chinese Medicine, Anhui University of Traditional Chinese Medicine, after water extraction and alcohol precipitation, and then vacuum freeze-dried, which contained baicalin and emodin, etc. LPS (Beijing Solepol Science and Technology Co., Ltd., purity $\geq 99\%$); FBS (Beijing Biyuntian Biotechnology Institute); DMEM/F12 medium (Corning, USA); PBS buffer (Beijing Biosun Biotechnology Co., Ltd.); fluorescently labeled TNF- α (Suzhou Desai Biotechnology Co., Ltd.); and albumin (Shanghai Aladdin Biochemical Technology Co., Ltd.).

2.1.2. Materials and instrument

Microscope (Nikon E600i), enzyme labeler (Thermo Scientific, USA), bench-top high-speed cryo-centrifuge (Sartorius AG, Switzerland), automatic biochemical analyzer (Beckman Coulter Inc., USA), and fluorescence quantitative PCR instrument (Bio-Rad Laboratories, USA).

2.1.3. Animal grouping and treatment

In this study, the experimental rabbits were divided into a control group, a blank group, and a test group (Wuwei Xiaodu Drink group) by random number table method, with 30 animals in each group.

2.2. Methods

The experimental group (Wuwei Xiaodu Drink group), blank group and control group were given an extract of Wuwei Xiaodu Drink orally, saline and amoxicillin (State Drug Permit H13021516 Shenwei Pharmaceutical Group Co., Ltd.) 20 mg/kg, dissolved in saline and then orally, respectively. The rabbits were weighed on the day of modeling and 12 weeks after modeling and the related evaluation indexes were measured. Extract of Wuwei Xiaodu Drink is composed of five traditional Chinese medicines: 15 g of honeysuckle, 6 g of wild chrysanthemum, 6 g of dandelion, 6 g of *Viola philippica*, 6 g of *Begonia fimbristipula* and so on. After the extraction and processing, the extract of Wuwei Xiaodu Drink can better retain the medicinal components and facilitate oral administration.

2.3. Observation indicators

Observe and analyze the changes in body mass before and after intervention, post-intervention inflammation-related factors and blood leukocyte count comparisons in the three groups.

2.4. Statistical methods

SPSS 21.0 statistical software was used to process the data. Measurement data were expressed as mean \pm standard deviation (SD), and a t -test was used, and count data were expressed as a percentage (%), an χ^2 test was used, and the difference was considered statistically significant at $P < 0.05$.

3. Results

3.1. Changes in body mass before and after intervention in three groups of rabbits

The changes in body mass of rabbits before and after intervention in the test group, control group and blank group were significantly different ($P < 0.05$), as shown in **Table 1**.

Table 1. Changes in body mass before and after intervention in three groups of rats

Group	Number of SD rabbits	Pre-intervention (g)	Post-intervention (g)	t	P
Test group	30	236.62 \pm 13.31	311.32 \pm 10.84	23.835	0.000
Control group	30	247.12 \pm 13.41	312.19 \pm 10.32	21.062	0.000
Blank group	30	243.54 \pm 13.32	223.28 \pm 9.51	6.780	0.000

Note: There was no statistical significance in the two-by-two comparison of the experimental group, control group and blank group before intervention ($P > 0.05$); after intervention, there was no statistical difference between the experimental group and the control group ($P > 0.05$); there was a statistical difference between the experimental group and the blank group ($P < 0.05$).

3.2. Inflammation-related factors and blood leukocyte counts in the three groups of rabbits after intervention

There were no statistical differences in calcitoninogen, C-reactive protein, and routine blood leukocyte counts between the test group and the control group ($P > 0.05$), and there were statistical differences in calcitoninogen, C-reactive protein, and routine blood leukocyte counts between the test group and the blank group ($P < 0.05$), as shown in **Table 2**.

Table 2. Inflammation-related factors and routine blood leukocyte counts in three groups of rabbits after intervention

Group	Number of SD rabbits	Calcitoninogen (ng/mL)	C-reactive protein (ng/mL)	Routine blood white blood cell count ($\times 10^9$)
Test group	30	0.32 \pm 0.11	8.19 \pm 0.23	8.21 \pm 0.31
Control group	30	0.33 \pm 0.21	8.08 \pm 0.30	8.10 \pm 0.32
Blank group	30	1.74 \pm 0.22	14.31 \pm 1.48	15.23 \pm 1.17
t_1		0.231	1.594	1.352
P_1		> 0.05	> 0.05	> 0.05
t_2		31.621	22.380	31.767
P_2		0.000	0.000	0.000

Note: t_1 and P_1 indicate the comparison results between the test group and the control group; t_2 and P_2 indicate the comparison results between the test group and the blank group.

4. Discussion

Spinal infections are infectious diseases of the bones and soft tissues of the spine caused by bacteria, fungi or other microorganisms. This infection is usually caused by the invasion of various pathogenic microorganisms such as *Staphylococcus aureus*, *Streptococcus sp.*, etc. into the spinal column, and these microorganisms enter into the vertebral canal through the blood circulation or direct invasion, causing inflammation, necrosis, and abscess formation of the soft tissues and bones. Spinal infections can be triggered by a variety of causes, including, but not limited to, bacterial infections, foreign bodies in the spinal canal, trauma, immunocompromise, and medical infections. Bacterial infections are purulent infections caused by bacteria invading the spinal canal, with common causative organisms being *Staphylococcus aureus* and *Staphylococcus albicans*. Foreign bodies in the spinal canal may cause infection due to compression of the spinal cord, nerve roots, discs and other areas. In addition, trauma to the spine may cause localized blood vessel rupture, which in turn can lead to infection. Immunocompromised and medical infections are also potential causes of spinal infections. Clinical symptoms of spinal infections are varied and typically include back pain, fever, chills, general malaise, and limited mobility. In addition, patients may also experience localized skin erythema, edema and increased skin temperature. In severe cases, the infection may invade the nervous system, leading to symptoms such as numbness and weakness in the limbs and even affecting normal activities. Measures to treat spinal infections mainly include antibiotic therapy and surgical intervention. Depending on the severity of the infection and the type of pathogen, doctors will choose the appropriate antibiotic for treatment. Surgical treatment may be required if the infection is severe and the localized lesion is large. Meanwhile, physiotherapy such as massage, hot packs and hot baths can also be used as an adjunctive treatment to promote blood circulation in the spine area and relieve muscle tension. Spinal infection refers to the exogenous invasion of bacteria, viruses and other pathogens into the human body, disrupting the balance of the body's internal environment and the emergence of local or systemic infection ^[3]. Its pathogenesis is related to host immune dysfunction, which activates neutrophils, monocytes and macrophages under the action of multiple factors, which in turn releases a large number of inflammatory mediators and triggers an inflammatory response in the body.

Firstly, the treatment of spinal infections, as a serious clinical problem, often involves the use of antibiotics, but the long-term use or abuse of antibiotics may lead to the development of drug resistance. Wuwei Xiaodu Drink, as a natural drug, with its broad-spectrum antimicrobial effect may provide a new option for the treatment of spinal infections, especially for drug-resistant strains of bacteria, and it may be of therapeutic efficacy ^[4]. Secondly, the efficacy of Wuwei Xiaodu Drink in clearing heat removing toxins and dissipating boils may help to alleviate the local inflammatory response caused by spinal infections and reduce the pain and discomfort of patients. By regulating the body's immune response, Wuwei Xiaodu Drink may help control the progression of infection and promote the subsidence of inflammation and tissue repair. In addition, Wuwei Xiaodu Drink may also play a role in the prevention of spinal infections ^[5]. By improving the body's resistance, it reduces the invasion and multiplication of pathogenic microorganisms, thus reducing the risk of spinal infection. However, it is worth noting that although Wuwei Xiaodu Drink may have some value in the spinal infection rabbit model, its specific mechanism of action, dose-effect relationship, and the safety of long-term use still need to be further researched and verified. In addition, due to the differences between animal models and humans, the efficacy and safety of Wuwei Xiaodu Drink in humans also need to be confirmed by more clinical trials.

Studies have shown that Wuwei Xiaodu Drink has good antibacterial effects against gram-negative bacilli such as *Staphylococcus aureus*, *Haemophilus influenzae* type A, and *Klebsiella pneumoniae* ^[6]. In this experiment, the tissue sections of the thoracic and lumbar spine of rabbits in the test group showed obvious inflammatory

infiltration, severe vacuolization of nucleus pulposus cells, edema, degeneration and necrosis of neuronal cells, and proliferation of astrocytes. At the same time, there was a statistical difference in calcitoninogen, C-reactive protein, and blood routine leukocyte count between the experimental group and the blank group ($P < 0.05$), and Extract of Wuwei Xiaodu Drink could significantly reduce the number of leukocytes in the serum after the infection, reduce the content of inflammatory markers blood routine leukocyte count, increase the splenic index, and improve the structure of the nucleus pulposus area after the infection. This may be closely related to the molecular mechanism of TCM for spinal infections.

Therefore, the research and development of drugs for spinal infections should focus on their effects on the host immune system and the interactions between different components, to obtain new drugs with higher efficacy. Wuwei Xiaodu Drink has a good bacteriostatic effect and inhibits the expression of LPS-induced inflammatory cytokines blood routine leukocytometer, C-reactive protein and calcitoninogen ^[7]. Studies have shown that there are interactions and synergistic effects between multiple components of traditional Chinese medicines, and their mechanisms of action in treating diseases are complex ^[8]. Honeysuckle is sweet and cold in nature, can clear heat and detoxify, with its light and clear evacuation, is one of the main herbs in Wuwei Xiaodu Drink, and its dosage is relatively large, which can play the effect of clearing heat and detoxification more effectively; wild chrysanthemum has the effect of dispersing wind and heat, detoxifying and eliminating oedema, and its dosage is moderate so that it can have a synergistic effect with honeysuckle without being too strong; dandelion clears heat and detoxifies, diuretic and diuretic, and its dosage is similar to that of wild chrysanthemum. Dandelion clears heat and removes toxins, induces diuresis and lymphatic drainage, and its dosage is the same as that of wild chrysanthemum, which jointly assists honeysuckle and strengthens the power of clearing heat and removing toxins ^[9-10]. This study confirmed the protective effect of Extract of Wuwei Xiaodu Drink on rabbits with spinal cord injury and preliminarily investigated that Extract of Wuwei Xiaodu Drink alleviated spinal cord nerve injury by down-regulating the expression of inflammatory cytokine calcitoninogen, reducing the release of inflammatory mediators, and decreasing the degree of tissue damage.

5. Conclusion

In conclusion, the Extract of Wuwei Xiaodu Drink can effectively alleviate pathological injury after spinal infection in rabbits and regulate the host immune response to play a role in protecting the organism, and its main mechanism of action may be:

- (1) Inhibit the expression of inflammatory cytokines calcitoninogen and C-reactive protein;
- (2) Enhance the proliferation ability of peripheral blood lymphocytes;
- (3) Promote the activity of spleen phagocytes;
- (4) Activate the expression of immune factors in spleen nucleoli;
- (5) Repair damaged spinal cord tissues.

However, it is worth noting that this study failed to exclude the possibility of other interfering factors, such as the animal's factors, feeding conditions, experimental methods, etc. It is necessary to expand the sample size further and repeat the verification.

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Mechanisms of G Protein-Coupled Receptors (GPCRs) in Inflammatory Pain and Their Therapeutic Targets

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Abstract: Inflammatory pain is a common and complex clinical symptom closely associated with many chronic inflammatory diseases, and its treatment has always faced significant challenges. As a receptor family playing a key role in cell signaling, G protein-coupled receptors (GPCRs) play an important role in the occurrence, development, and regulation of inflammatory pain. GPCRs not only regulate inflammatory responses and pain sensitivity through cell membrane signaling pathways but also interact complexly with ion channels, immune cells, and metabolites, affecting the dynamic balance of the neuro-inflammatory-immune network. Studies have shown that specific GPCR subtypes (such as Mrgpr, GPR37, etc.) play a unique role in inflammatory pain perception and inflammation resolution, providing targets for the development of new analgesic drugs. In addition, biased ligands of GPCRs and their endosome targeting effects open up new directions for reducing drug side effects and improving efficacy. This article systematically summarizes the biological functions of GPCRs in inflammatory pain, potential drug targets, and future research directions.

Keywords: G protein-coupled receptors; Inflammatory pain; Biased ligands; Endosome-targeted drugs

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1. Clinical significance of inflammatory pain

Inflammatory pain is a common type of pain seen in clinical settings, often associated with tissue damage or inflammatory responses. Patients may experience symptoms such as persistent pain, tenderness, and limited movement. This type of pain not only affects the physical function of patients but also severely disrupts their daily lives, including sleep quality, emotional state, and social interactions ^[1]. For example, various diseases such as osteoarthritis, rheumatoid arthritis, and inflammatory bowel disease are accompanied by significant inflammatory pain symptoms, affecting the health of millions of people globally ^[2]. The clinical significance of inflammatory

pain lies not only in its widespread incidence and high disability rate but also in its complexity and difficulty to eradicate. The inflammatory response is the body's defense mechanism against harmful stimuli, but when it is excessive or persistent, it can lead to tissue damage and pain sensitization, resulting in inflammatory pain ^[3]. This type of pain involves not only the activation of the peripheral nervous system but also the participation of the central nervous system, forming a complex neural circuit.

2. Signal transduction characteristics and research status of G protein-coupled receptors

The basic structural feature of G protein-coupled receptors (GPCRs) is their seven transmembrane helix (7TM) structure. These helices consist of approximately 20–30 hydrophobic amino acids that pass through the cell membrane in an α -helical form, forming a transmembrane domain. GPCRs recognize various signaling molecules in the extracellular environment, such as neurotransmitters, hormones, chemokines, and inflammatory mediators, and convert these signals into intracellular biological effects. These receptors are widely distributed in the human body and are involved in almost all physiological processes, including neurotransmission, immune response, inflammatory response, cardiovascular function, and metabolic regulation ^[4]. The widespread distribution and diverse functions of GPCRs make them important therapeutic targets for many diseases. In recent years, significant progress has been made in studying the role of GPCRs in inflammatory pain. Increasing evidence suggests that multiple GPCRs play important roles in the occurrence and development of inflammatory pain. For example, certain GPCRs can activate inflammatory cells (such as macrophages and mast cells) to release inflammatory mediators, exacerbating inflammatory responses and pain sensitization ^[5]. Researchers have found that targeting these specific GPCRs can effectively relieve inflammatory pain. For instance, antagonists targeting the capsaicin receptor (TRPV1) can reduce pain caused by inflammation ^[6].

3. Mechanisms of GPCRs in inflammatory pain

3.1. Cell membrane surface signal transduction

3.1.1. Early signaling events after GPCR binding with ligands

The activation of GPCRs is a critical initiating step in cell membrane surface signal transduction. This process begins with the specific binding of ligands to GPCRs. Ligands are diverse, including peptides, small molecules, lipids, etc., and they interact with the transmembrane region of GPCRs through unique molecular structures. The high specificity of this interaction determines the accuracy of signal transmission. After ligands bind to GPCRs, it leads to conformational changes in the receptors, which are dynamic and crucial for downstream signaling pathways. For example, studies on the neurokinin 1 receptor (NK1R) have found that the binding of substance P (SP) to NK1R causes conformational changes in the receptor, activating downstream signaling pathways, including the activation of G proteins and the recruitment of β -arrestin ^[7].

3.1.2. Activation mechanism of G protein-dependent signaling pathways

The activation of GPCRs is primarily achieved through interactions with heterotrimeric G proteins, which consist of α , β , and γ subunits. G proteins are classified into multiple subtypes, such as Gs, Gi/o, and Gq/11 based on their α subunits, and each subtype activates different downstream effectors. Gi/o proteins inhibit the activity of AC, reducing cAMP levels. Gq/11 proteins activate phospholipase C (PLC), leading to the hydrolysis of

phosphatidylinositol-4,5-bisphosphate (PIP₂) to produce inositol triphosphate (IP₃) and diacylglycerol (DAG), thereby increasing intracellular calcium ion concentration and activating protein kinase C (PKC). Changes in these second messenger levels play important roles in inflammatory pain.

3.1.3. β -arrestin-mediated signal transduction

β -arrestin was initially recognized as a key regulator of GPCR desensitization and endocytosis. When GPCRs are activated, β -arrestin is recruited to the receptors through phosphorylation by G protein-coupled receptor kinases (GRKs), preventing further activation of G proteins by the receptors and leading to signal pathway attenuation. Simultaneously, β -arrestin can promote receptor endocytosis, transporting receptors from the cell membrane to endosomes, further reducing the number of receptors on the cell surface and achieving signal termination. However, research has found that β -arrestin not only participates in GPCR desensitization and endocytosis but also acts as a signal adaptor protein, mediating non-canonical signaling pathways. For instance, β -arrestin can activate the MAPK pathway, affecting cell growth, differentiation, and inflammatory responses.

3.2. Receptor endocytosis and endosomal signaling

3.2.1. Signal transduction characteristics of GPCR endocytosis-mediated processes

GPCR endocytosis is a dynamic process where receptors are encapsulated in vesicles through a clathrin-mediated pathway, ultimately forming endosomes. Endosomes are not merely sites for signal termination but can also serve as platforms for signal transduction. During endocytosis, receptors can still bind to signaling molecules such as G proteins and β -arrestin, maintaining or altering signal transmission characteristics. In endosomes, the spatial localization and temporal dynamics of signaling molecules can be regulated, providing more possibilities for signal transduction. This indicates that GPCR endocytosis not only affects signals on the cell membrane surface but also profoundly impacts intracellular signal transmission.

3.2.2. Regulatory role of endocytosis pathways in pain persistence

GPCR endocytosis is a crucial regulator of pain persistence. When GPCRs are activated, endocytosis can lead to the removal of receptors from the cell membrane surface, reducing the sensitivity of cells to painful stimuli. However, if the endocytosis process is abnormal, such as blocked endocytosis or continuous activation of receptors in endosomes, it may result in persistent transmission of pain signals. Additionally, some natural variants of GPCRs exhibit abnormal signal transduction and endocytosis trafficking, leading to the persistent presence of pain.

3.2.3. Potential value of novel endosome-targeted therapies

Due to the significant role of endocytosis pathways in regulating pain persistence, drug development targeting these pathways has emerged as a new research direction. Traditional GPCR antagonists primarily act on receptors on the cell membrane surface, but receptors in endosomes can still transmit signals, limiting the effectiveness of traditional drugs. Therefore, developing novel drugs that can target endosomes is of great importance. Some studies have begun exploring the possibilities of endosome-targeted therapies, such as modifying the lipid solubility and pK_a values of GPCR antagonists to make them easier to enter and remain in endosomes, thereby continuously inhibiting endosomal signaling ^[7]. Additionally, nanoparticle-encapsulated drugs represent a potential endosome-targeted treatment approach, which can precisely deliver drugs to endosomes, enhancing their therapeutic efficacy.

3.3. Interaction with ion channels

3.3.1. GPCR regulation of calcium/sodium channels

GPCRs not only regulate intracellular second messenger levels and signaling pathways through signal molecules like G proteins and β -arrestin, but they also directly modulate neuronal excitability by interacting with ion channels. Calcium and sodium channels are key regulators of neuronal excitability and play crucial roles in pain signal transmission. GPCRs can regulate the function of calcium and sodium channels through various mechanisms.

3.3.2. Connection between ion channels and pain sensitivity

Ion channels play a central role in pain signal transmission. Voltage-gated sodium channels (Nav), particularly the Nav1.7, Nav1.8, and Nav1.9 subtypes, are highly expressed in nociceptive neurons and are involved in pain generation and transmission. Increased activity of these ion channels enhances neuronal excitability, leading to a lowered pain threshold and increased pain sensitivity. By modulating the activity of these ion channels, GPCRs can alter pain thresholds and sensitivity.

4. Novel therapeutic strategies in inflammatory pain

4.1. Clinical research and applicability of traditional GPCR blockers

GPCRs have a long history as drug targets, and many early drugs, such as antihistamines and beta-blockers, are actually GPCR antagonists or agonists widely used in clinical practice with demonstrated efficacy. In the field of inflammatory pain treatment, the development of traditional GPCR blockers has been accompanied by challenges. Although these drugs can provide pain relief in certain cases, their efficacy is often unsatisfactory, and they are frequently associated with side effects, especially in the management of chronic pain^[8]. Therefore, in clinical practice, it is essential to select appropriate drugs based on the specific conditions of patients and closely monitor their efficacy and adverse reactions to facilitate timely treatment adjustments.

4.2. Biased ligands and other novel drug development directions

4.2.1. Research progress of biased ligands

Biased ligands represent a significant advancement in GPCR drug development in recent years. These ligands can selectively activate specific signaling pathways of GPCRs, achieving more precise drug effects^[9]. Unlike traditional drugs that simply block or activate the entire GPCR, biased ligands bind to different regions of the receptor, preferentially activating certain downstream signaling pathways while avoiding the activation of undesired pathways. This approach reduces side effects and enhances therapeutic efficacy. The development of biased ligands has brought new hope to the treatment of inflammatory pain. By screening and designing ligands that preferentially activate specific signaling pathways, researchers can develop safer and more effective analgesics.

4.2.2. Development and advantages of endosome-targeted drugs

Endosome-targeted drugs represent another emerging direction in GPCR drug development. This strategy involves delivering drugs to intracellular endosomes, where they exert their effects. Compared to traditional drugs, endosome-targeted drugs offer multiple advantages, including more precise regulation of GPCR activity and reduced systemic exposure, thereby lowering the risk of side effects.

4.2.3. Potential applications of natural products and toxin-based drugs

Natural products and toxin-based drugs hold potential value in the treatment of inflammatory pain. Numerous biologically active compounds exist in nature, such as plant extracts, marine biotoxins, and microbial metabolites. These compounds can interact with GPCRs to produce analgesic and anti-inflammatory effects ^[10]. Currently, researchers are actively exploring the potential applications of natural products and toxin-based drugs in inflammatory pain treatment. By screening, modifying, and optimizing these compounds, new drug candidates can be developed. Some studies have successfully transformed natural products or toxin-based drugs into clinical medications. For instance, certain capsaicin-like compounds have been used to treat neuropathic pain. However, research on natural products and toxin-based drugs still faces challenges, including compound extraction, purification, pharmacological activity evaluation, and toxicity assessment.

4.3. GPCR gene polymorphism and precision medicine

4.3.1. Differences in GPCR expression profiles and individualized drug strategies

GPCR gene polymorphism refers to individual differences in *GPCR* gene sequences. These differences can affect GPCR expression levels, structures, and functions, leading to variations in responses to the same drug among different individuals. For example, certain *GPCR* gene polymorphisms can result in increased or decreased receptor expression levels, altered ligand binding capabilities, or modified signal transduction efficiency.

In the treatment of inflammatory pain, *GPCR* gene polymorphism can directly influence drug efficacy. For instance, studies have found that polymorphisms in opioid receptor genes are associated with the analgesic effects and side effects of opioids. Patients carrying certain gene polymorphisms may respond poorly to opioids, requiring higher doses to achieve the same analgesic effect. Understanding the impact of *GPCR* gene polymorphism on drug responses can assist doctors in developing more personalized treatment plans. By testing patients' GPCR genotypes, it is possible to predict their responses to specific drugs, allowing for the selection of the most appropriate medication and dosage.

4.3.2. Challenges and opportunities from the perspective of precision medicine

Precision medicine based on *GPCR* gene polymorphism represents a significant development direction in the field of inflammatory pain treatment. However, several challenges still need to be addressed to achieve this goal. Firstly, technical limitations pose a challenge. Although gene detection technology has matured considerably, further technological advancements are needed to comprehensively understand the impact of *GPCR* gene polymorphism on drug responses. This includes developing faster and more accurate gene detection methods and establishing large-scale gene databases. Additionally, functional studies on *GPCR* gene polymorphism remain challenging and require the use of high-throughput screening and bioinformatics approaches to deeply analyze the biological significance of different gene polymorphisms.

Secondly, ethical considerations are crucial in the development of precision medicine. Issues such as privacy protection in gene testing, misuse of genetic information, and genetic discrimination need to be addressed through appropriate laws, regulations, and ethical guidelines. Furthermore, the high cost of precision medicine must be considered, ensuring that all patients can equally benefit from its advantages.

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Effects of Goal-Directed Fluid Therapy on Postoperative Delirium in Elderly Hip Fracture Patients

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Abstract: *Objective:* To analyze the effects of goal-directed fluid therapy on postoperative cerebral oxygen metabolism level (rScO₂), blood pressure (MAP), heart rate (HR), and incidence of intraoperative hypotension and delirium in elderly hip fracture patients. *Methods:* Sixty-six elderly patients who underwent hip fracture surgery under intrathecal anesthesia in a hospital between October 2023 and September 2024 were selected and divided into a control group and an observation group using the mean score method, each with 33 cases. Both groups were given dexmedetomidine 10 min before surgery, and the control group was treated with conventional intraoperative fluid replacement, while the observation group was treated with goal-directed fluid therapy. The rScO₂, MAP, HR, the incidence of intraoperative hypotension, and the index of delirium MMSE score at preoperative (T₀), subarachnoid block for 5 min (T₁), and surgical 30 min (T₂) were observed and compared between the two groups. *Results:* The difference between the left rScO₂ and right rScO₂ levels at T₀ between the two groups was not significant ($P > 0.05$), but the left rScO₂ and right rScO₂ levels were significantly higher in the observation group than in the control group at T₁ and T₂ ($P < 0.05$); compared with the group at T₀, the patients in the control group at T₁, left rScO₂ and right rScO₂ levels were significantly lower at T₂ ($P < 0.05$); the left rScO₂ and right rScO₂ levels at T₁ and T₂ of patients in the observation group were higher than those at T₀, and the difference was not statistically significant ($P > 0.05$). There was no statistically significant difference in the levels of MAP and HR at T₀ between the two groups ($P > 0.05$), and the levels of MAP and HR at T₁ and T₂ were significantly higher in the observation group than those of the control group ($P < 0.05$); compared with the group's levels at T₀, there was a significant decrease in the levels of MAP and HR in the control group at T₁ and T₂, with the difference being statistically significant ($P < 0.05$); HR at T₁ was significantly lower than that at T₀ in patients in the observation group ($P < 0.05$); however, the difference between MAP at T₁ and T₂ and HR at T₂ compared with that at T₀ was not statistically significant ($P > 0.05$); the incidence of intraoperative hypotension in the observation group (3.03%) was significantly lower than that of the control group (24.24%) ($P < 0.05$). There was no statistically significant difference in MMSE scale scores between the two groups of patients in the preoperative 1d ($P > 0.05$); compared with the preoperative 1d in the group, there was a significant decrease in MMSE scale scores in the postoperative 1d and 3d in the two groups, with the observation group being significantly higher than the control group ($P > 0.05$); the difference between MMSE scale scores in the postoperative 1d and 3d in the control group and those of the preoperative 1d in the control group had statistical significance ($P < 0.05$); the difference between

the postoperative 1d and 3d MMSE scale scores of the observation group and the preoperative 1d was not statistically significant ($P > 0.05$). *Conclusion:* During the implementation of intrathecal anesthesia for hip fracture surgery in the elderly, the application of goal-directed fluid therapy can improve the oxygen metabolism of cerebral tissues, reduce the fluctuation of intraoperative blood pressure and heart rate, lower the incidence of postoperative hypotension, and help to promote the recovery of patients' postoperative cognitive functions.

Keywords: Goal-directed fluid therapy; Elderly hip fracture; Intrathecal anesthesia; Postoperative delirium

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1. Introduction

Hip fracture is a common traumatic disease in the elderly population, and its high incidence and poor prognosis have become an important challenge for global public health. With the aging of the population, the demand for surgical treatment of hip fractures in the elderly is increasing year by year, but the incidence of postoperative complications remains high, which significantly affects patients' functional recovery and long-term quality of survival ^[1]. Postoperative delirium (POD) is an acute, fluctuating cognitive dysfunction manifested by inattention, altered level of consciousness, and disorganized thinking, which occurs through a complex mechanism involving multiple factors such as neuroinflammation, oxidative stress, and abnormal cerebral perfusion ^[2]. In elderly hip fracture patients, the incidence of POD can be as high as 20–40% and is strongly associated with long-term cognitive decline and increased mortality. Therefore, it is clinically important to explore modifiable risk factors for POD and develop targeted intervention strategies ^[3]. Intraoperative hemodynamic instability, especially hypotension (mean arterial pressure, MAP < 65 mmHg) and imbalance of cerebral oxygen metabolism, are important triggers of POD. Elderly patients are often combined with decreased vascular elasticity, autonomic dysfunction, and insufficient cardiac reserve, and are more prone to intraoperative blood pressure fluctuations and hypoperfusion ^[4]. Regional cerebral oxygen saturation (rScO₂) is a non-invasive indicator of the balance between cerebral oxygen supply and demand, and a decrease in intraoperative rScO₂ levels may directly impair neuronal function by inducing cerebral ischemia and energy metabolism disorders, which in turn increases the risk of delirium ^[5]. In addition, abnormal fluctuations in heart rate (HR) (e.g., tachycardia or severe bradycardia) may also be indirectly involved in the development of POD by affecting cardiac output and cerebral perfusion. Goal-directed fluid therapy (GDFT) is an individualized fluid management strategy based on hemodynamic monitoring aimed at maintaining intraoperative hemodynamic stability by optimizing cardiac output and tissue perfusion ^[6]. In recent years, the role of GDFT in reducing postoperative complications has attracted much attention, but its effect on POD in elderly hip fracture patients is controversial. The aim of this study was to investigate the effect of GDFT on postoperative delirium in elderly hip fracture patients, and to focus on its association with intraoperative rScO₂, MAP, HR, and hypotensive events, with a view to achieving the goal of improving the quality of postoperative rehabilitation in elderly hip fracture patients.

2. Information and methodology

2.1. General information

Sixty-six cases of elderly patients who underwent hip fracture surgery under intralesional anesthesia in a hospital

between October 2023 and September 2024 were selected and divided into a control group and an observation group using the mean score method, each with 33 cases. In the control group, there were 15 males and 18 females, with an age range of 65–89 years, a mean of 76.21 ± 6.82 years; body mass index (BMI): 23.50 ± 3.22 kg/m²; and operation time: 55.4 ± 12.6 min. In the observation group, there were 16 males and 17 females, with an age range of 64–88 years, a mean of 75.80 ± 7.15 years; BMI: 23.8 ± 3.0 kg/m²; operation time: 56.9 ± 11.9 min. The differences in general information between the two groups were not statistically significant ($P > 0.05$) and were comparable.

Inclusion criteria: (1) age ≥ 64 years; (2) diagnosis of unilateral hip fracture (femoral neck or intertrochanteric fracture); (3) American Society of Anesthesiologists (ASA) classification grade II to III; (4) absence of severe cardiac, pulmonary, hepatic, and renal dysfunction; and (5) preoperative Mini-Mental State Examination (MMSE) score ≥ 24 to exclude baseline cognitive dysfunction.

Exclusion criteria: (1) presence of severe cerebrovascular disease or history of dementia; (2) long-term use of psychotropic drugs; (3) intraoperative conversion to general anesthesia; (4) incomplete clinical data or loss of visits.

2.2. Methodology

All patients were fasted for 6 h and water-fasted for 2 h. After admission to the room, intravenous access was established, and real-time blood pressure was monitored by radial artery puncture catheterization. Electrocardiogram (ECG), heart rate (HR), mean arterial pressure (MAP), and pulse oximetry (SpO₂) were continuously monitored, and 2 L/min oxygen was administered by mask. Thirty minutes before position placement, 0.375% ropivacaine (Jiangxi Hengrui Medicine Co., Ltd., State Pharmaceutical Certificate: H20060137) was used to perform an iliac fascia block on the affected side to reduce operation-related pain. Anesthesia was performed by subarachnoid block with isogravimetric ropivacaine (10 mg), and dexmedetomidine (0.5 µg/kg, 15-min infusion) was injected intravenously 10 min before skin incision, and the intraoperative dose of 0.5 µg/kg/h was maintained, and the drug was discontinued 10 min before the end of the operation. Intraoperative electric blankets were applied to maintain body temperature, and postoperative intravenous self-controlled analgesia (PCA) was used in all cases to optimize pain management.

The control group was treated with conventional intraoperative fluid replacement. The total amount of intraoperative fluid infusion was supplemented with crystalloid fluid (e.g. lactated Ringer's solution or saline) based on the patient's body weight, fasting time, intraoperative blood loss, and urine output. The rate of fluid replenishment was maintained at 6–8 mL/kg/h and dynamically adjusted according to hemodynamic parameters (e.g. MAP, urine output). If intraoperative bleeding was large (> 500 mL), colloidal fluids (e.g., hydroxyethyl starch) were supplemented as appropriate to maintain effective circulating blood volume. If the patient's MAP decreased by $> 20\%$ from the preoperative baseline value for more than 1 min, norepinephrine 4 µg (Harvest Pharmaceuticals) was pushed intravenously, and the dose was repeated if necessary. Deleterious, suspended red blood cells were infused when the red blood cell pressure (HCT) was $< 25\%$. The goal of routine rehydration is to maintain hemodynamic stability while avoiding abnormal tissue perfusion due to volume overload or underload.

The observation group was treated with goal-directed fluid therapy. The basal fluid requirement was first maintained with sodium lactate Ringer's solution 1–2 mL/kg/h, while volume responsiveness was assessed by dynamic monitoring of stroke volume per beat (stroke volume, SV). When the monitoring showed $SV > 10\%$, 200 mL of hydroxyethyl starch 130/0.4 solution was rapidly infused (done within 5 minutes), and the trend of SV was

observed. If the decrease in SV after infusion exceeded 10% of the baseline value, it was judged to be positive for volume responsiveness, and an additional 200 ml of colloidal solution of the same specification was infused until the SV parameter was stabilized below the 10% threshold, so as to realize individualized and precise rehydration therapy.

2.3. Observation indicators

- (1) The cerebral oxygen metabolism level (rScO₂), blood pressure (MAP), heart rate (HR), and the occurrence of intraoperative hypotension were observed and recorded at preoperative (T₀), subarachnoid block for 5 min (T₁), and surgical 30 min (T₂) in both groups.
- (2) The patients' memory, attentional calculation, orientation, and language ability were assessed using the Mini-Mental State of Intelligence Scale (MMSE), with 30 questions and a total score range of 0–30, and an MMSE score of < 27 was classified as cognitive dysfunction.

2.4. Statistical treatment

SPSS 21.0 statistical software was used to process the data, and the measurement information was expressed as mean ± standard deviation (SD) with *t*-test, and the count information was expressed as percentage (%) with χ^2 test, and the difference was considered statistically significant with $P < 0.05$.

3. Results

3.1. Comparison of postoperative cerebral oxygen metabolism levels between the two groups of patients

The differences in the levels of left rScO₂ and right rScO₂ at T₀ between the two groups were not significant ($P > 0.05$), but the levels of left rScO₂ and right rScO₂ at T₁ and T₂ in the patients of the observation group were higher than those of the control group, and the differences were statistically significant ($P < 0.05$); compared with that of the group at T₀, the levels of left rScO₂ and right rScO₂ in the patients of the control group were significantly lower at T₁ and T₂, the levels of left rScO₂ and right rScO₂ were significantly lower than those in the control group at T₂, and the difference was statistically significant ($P < 0.05$); the levels of left rScO₂ and right rScO₂ in patients of the observation group at T₁ and T₂ compared with those at T₀, and the difference was not statistically significant ($P > 0.05$). See **Table 1**.

Table 1. Comparison of postoperative cerebral oxygen metabolism levels (rScO₂) between the two groups (mean ± SD, %)

Groups	Left rScO ₂			Right rScO ₂		
	T ₀	T ₁	T ₂	T ₀	T ₁	T ₂
Control group ($n = 33$)	72.79 ± 4.87	65.39 ± 5.06 [#]	62.16 ± 4.12 [#]	71.25 ± 4.52	64.41 ± 4.12 [#]	61.13 ± 3.98 [#]
Observation group ($n = 33$)	73.14 ± 4.98	70.83 ± 4.89	69.97 ± 7.72	70.88 ± 4.36	68.78 ± 5.74	67.94 ± 7.24
<i>t</i>	0.2887	4.4410	5.1271	0.3384	1.6736	1.9984
<i>P</i>	0.7738	< 0.001	< 0.001	0.7361	0.0991	0.0499

Note: [#] $P < 0.05$ when compared to within-group T₀.

3.2. Comparison of blood pressure, heart rate, and the occurrence of intraoperative hypotension between the two groups of patients

There was no statistically significant difference in the levels of MAP and HR at T₀ between the two groups ($P > 0.05$), and the levels of MAP and HR at T₁ and T₂ were higher than those of the control group in the observation group, and the difference was statistically significant ($P < 0.05$); compared with that of the group at T₀, the levels of MAP and HR were significantly lower at T₁ and T₂ in the control group, and the difference was statistically significant ($P < 0.05$); HR at T₁ was lower than that at T₀ in patients in the observation group, and the difference was statistically significant ($P < 0.05$); however, the differences between MAP at T₁, T₂ and HR at T₂ compared with that at T₀ were not statistically significant ($P > 0.05$); the incidence of intraoperative hypotension in patients in the observation group (3.03%) was lower than that of the control group (24.24%), and the difference was statistically significant ($P < 0.05$). See **Table 2**.

Table 2. Comparison of blood pressure, heart rate, and the occurrence of intraoperative hypotension between the two groups of patients

Groups	MAP (mmHg)			HR (beats/min)			Incidence of hypotension [<i>n</i> (%)]
	T ₀	T ₁	T ₂	T ₀	T ₁	T ₂	
Control group (<i>n</i> = 33)	97.26 ± 5.19	94.62 ± 5.47*	92.32 ± 3.11*	86.39 ± 5.34	79.93 ± 4.75*	82.14 ± 4.08*	8 (24.24)
Observation group (<i>n</i> = 33)	98.18 ± 6.13	97.87 ± 6.16	95.43 ± 4.31	86.57 ± 5.82	82.98 ± 4.43*	84.41 ± 4.73	1 (3.03)
<i>t</i>	0.6580	2.2663	3.3614	0.1309	2.6975	2.0876	4.6316
<i>P</i>	0.5129	0.0268	0.0013	0.8963	0.0089	0.0408	0.0314

Note: * $P < 0.05$ when compared to within-group T₀.

3.3. Comparison of preoperative and postoperative delirium MMSE scores between the two groups of patients

There was no statistically significant difference in the preoperative 1d MMSE scale scores between the two groups ($P > 0.05$); compared with the preoperative 1d in the group, there was a significant decrease in the postoperative 1d and 3d MMSE scale scores in both groups, and the observation group was higher than the control group, and the difference was not statistically significant ($P > 0.05$); compared with the preoperative 1d in the control group, the difference between the postoperative 1d and 3d MMSE scale scores in the control group was statistically significance ($P < 0.05$), and the difference between the 1d and 3d postoperative MMSE scale scores of the observation group compared with the preoperative 1d was not statistically significant ($P > 0.05$). See **Table 3**.

Table 3. Comparison of preoperative and postoperative delirium MMSE scores between the two groups (mean ± SD, points)

Groups	1d preoperative	1d postoperative	3d postoperative
Control group (<i>n</i> = 33)	28.16 ± 1.22	25.72 ± 2.06 ^a	26.24 ± 1.67 ^a
Observation group (<i>n</i> = 33)	28.17 ± 1.14	27.86 ± 1.74	27.39 ± 2.12
<i>t</i>	0.0344	4.5590	2.4479
<i>P</i>	0.9727	< 0.001	0.0171

Note: ^a $P < 0.05$ when compared with 1d preoperatively in the group.

4. Discussion

Elderly hip fracture patients often have a variety of underlying diseases, with decreased physiological reserve function, poor tolerance to anesthesia and surgery, and intraoperative cerebral hypoxia easily triggered by hemodynamic fluctuations, inadequate tissue perfusion, and other factors, which in turn increase the risk of postoperative delirium. In addition, the vascular elasticity of elderly patients is reduced and sensitive to volume changes, and traditional rehydration strategies are prone to lead to hypotension or cardiac failure, further aggravating cerebral tissue hypoxia^[7]. Therefore, exploring a fluid therapy strategy that optimizes hemodynamic stability and improves cerebral oxygen metabolism is important for reducing the incidence of postoperative delirium and improving patient prognosis. Conventional fluid replacement therapy mostly relies on empirical infusion or static parameters (e.g., blood pressure, urine output), lacks individualized regulation, is difficult to accurately reflect the patient's volume status, and fails to identify and correct such problems in a timely manner, which can easily lead to an imbalance between cerebral oxygen supply and demand and increase the risk of postoperative delirium^[8]. Goal-directed fluid therapy is an individualized rehydration strategy based on dynamic hemodynamic indices (e.g., volume per beat variability, cardiac output, etc.), aiming to maintain tissue perfusion and oxygen supply by optimizing cardiac preload. It centers on monitoring patient volume responsiveness in real time to avoid blind rehydration or volume insufficiency^[9]. In elderly patients, GDFT may improve cerebral oxygen metabolism by maintaining a stable hemodynamic state and reducing hypotensive events.

The results of this study showed that the observation group had significantly higher rScO₂ levels than the control group at T₁ and T₂ time points, and had more stable MAP and HR, and a lower incidence of intraoperative hypotension (3.03% vs. 24.24%), suggesting that GDFT can effectively maintain stable cerebral oxygen metabolism and hemodynamics. The postoperative MMSE scores of the control group decreased significantly, whereas there was no statistically significant difference in the change of the scores of the observation group, suggesting that GDFT may alleviate postoperative cognitive impairment by improving the balance of cerebral oxygen supply and demand. Specifically, GDFT reduces the risk of delirium by optimizing cardiac output and tissue perfusion, avoiding cerebral hypoxia and hypotension caused by conventional rehydration^[10].

5. Conclusion

In conclusion, the application of goal-directed fluid therapy in geriatric hip fracture surgery reduces cerebral hypoxic events and maintains neurological stability, and the long-term effects of GDFT on delirium and the specific pathophysiological pathways need to be further explored in the future.

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Disclosure statement

The authors declare no conflict of interest.

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Analysis of the Mechanism of Centrifugal Contraction Training to Enhance Muscle Strength in Sports Rehabilitation

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Abstract: Centrifugal contraction training has emerged as a powerful technique in sports rehabilitation, gaining attention for its ability to enhance muscle strength and promote recovery from various injuries. Unlike concentric contraction, which involves muscle shortening, eccentric contraction involves muscle lengthening under tension, leading to distinct physiological adaptations. This paper explores the physiological mechanisms underlying centrifugal contraction training, including its effects on muscle fibers, strength, and endurance. It also examines the neural adaptations triggered by eccentric training, such as increased motor unit recruitment and muscle fiber activation.

Keywords: Exercise intervention strategies; Sarcopenia; Systematic review; Mechanism; Clinical practice

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1. Introduction

The field of sports rehabilitation has evolved significantly with the increasing recognition of eccentric (centrifugal) contraction training as a critical component of recovery and strength development. Eccentric training, especially in the context of muscle injury rehabilitation, offers unique advantages over traditional concentric methods by promoting greater muscle force production and improved muscle healing. Recent research has focused on understanding the physiological mechanisms of eccentric contractions, including their impact on muscle fiber types, strength gains, and neural adaptations.

2. Overview of centrifugal contraction training

2.1. Definition and characteristics of centrifugal contraction

Eccentric contraction is a form of contraction in which muscles are stretched by external forces while actively contracting (see **Figure 1c**), the core feature of which is the dynamic contradiction of “contraction and elongation.”

For example, when the quadriceps control body descent in a squat, muscle fibers generate tension to resist gravity, but the overall muscle length is elongated. Compared to centripetal contractions (muscle shortening) and isometric contractions (muscle length unchanged), centrifugal contractions produce a higher mechanical output (peak force 20–40% higher than centripetal contractions), but lower energy expenditure (50% less ATP utilization). The physiological mechanism involves the “slip effect” of the myosin head with actin—when the myotome is stretched under external load, it maintains a transverse bridge connection, leading to tension accumulation and elastic potential energy storage in connective tissues such as tendons. Centrifugal contraction is also a major cause of muscle microinjury (e.g., delayed DOMS) due to breaking of the myotome Z line and inflammation, but long-term adaptation can promote muscle hypertrophy and strength gain ^[1].

2.2. Comparison of centrifugal contraction with other muscle contraction types

Figure 1 compares the patterns of muscle contraction through three stages:

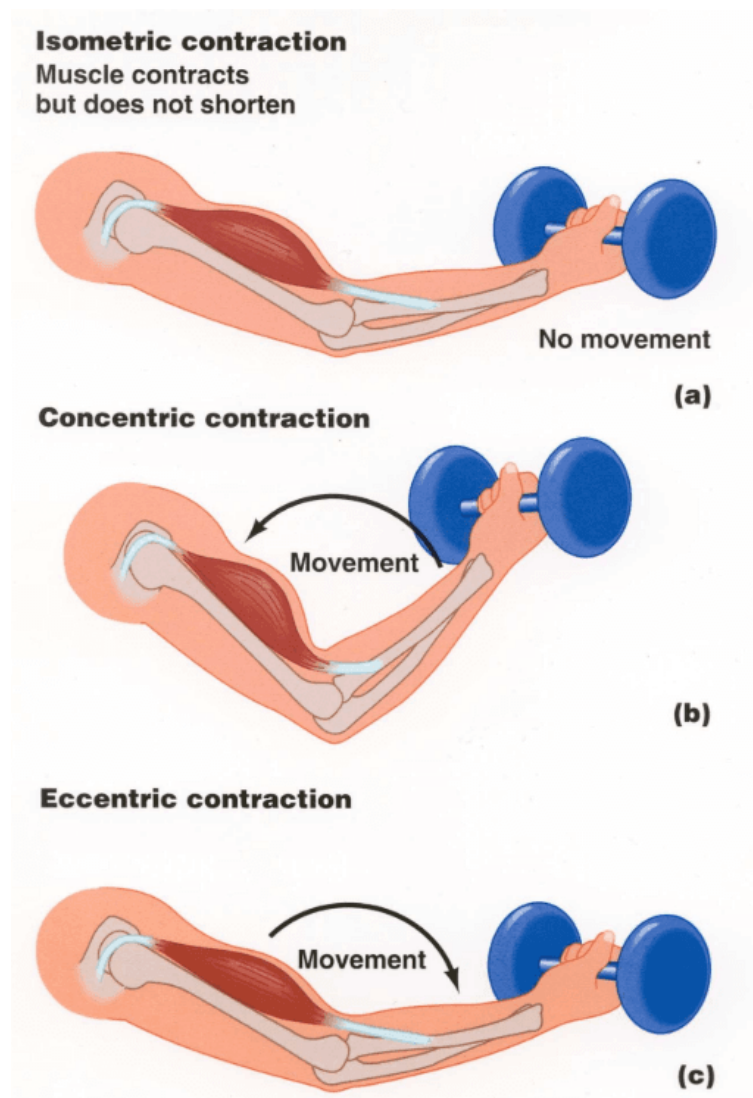


Figure 1. Three stages of muscle contraction

Isometric contraction: Muscle tension is generated but the length remains unchanged (such as plank support), and there is no joint movement (“No movement” in **Figure 1**), which is mainly used to maintain stable posture and moderate energy consumption ^[2];

Concentric contraction: Muscle shortening and overcoming resistance (e.g., dumbbell bending and lifting stage, **Figure 1a**), high mechanical efficiency but low force output, and aerobic metabolism;

Centrifugal contraction (**Figure 1c**): Muscle elongation under tension (e.g., slow dumbbell lowering stage), maximum force output, and stronger activation of fast muscle fibers (type II) (30% higher EMG signal amplitude), but prone to ultrastructural damage of muscle fibers (e.g. troponin release) ^[3].

Key differences: The force-velocity curve of centrifugal contraction is negatively correlated (the faster the speed, the greater the force), while centripetal contraction is positively correlated; Neural control of centrifugal movements relies more on inhibitory signals (such as Golgi tendon organ feedback) to reduce the risk of excessive strain.

2.3. Basic principle and application of centrifugal contraction training

Centrifugal contraction training is a training method to optimize muscle function and structure by strengthening the ability of muscles to bear loads under elongated conditions. Its core principles are based on the maximization of mechanical tension and metabolic adaptive regulation. During centrifugal contractions (as shown in **Figure 1c**), the muscles are stretched by external forces while actively contracting, such as the lowering phase of a dumbbell bend or the descending phase of a squat ^[4]. At this time, the tension generated by muscle fibers is significantly higher than that generated by centripetal contraction (up to more than 120%).

From a metabolic point of view, ischemia and accumulation of metabolites (such as lactic acid and reactive oxygen species) caused by centrifugal contraction can cause mild metabolic stress, stimulate the proliferation and differentiation of satellite cells, and accelerate muscle repair and hypertrophy. In addition, the preferential activation of fast muscle fibers (type II) by centrifugation (EMG signal amplitude is 30% higher than centripetal contraction) makes it an effective means to improve explosive power and anaerobic capacity. In terms of neural adaptation, centrifugal training significantly improves force output efficiency and motor stability by enhancing motor unit synchronization (especially high-threshold motor unit recruitment) and optimizing neuromuscular control (such as adaptive regulation of feedback inhibition of Golgi tendon organs) ^[5].

In clinical and sports practice, centrifugal contraction training is widely used and targeted:

Rehabilitation medicine: For the recovery of tendon injuries (such as Achilles tendinitis, patellar tendinopathy), through progressive centrifugal load (such as “Nordic hip training”) to stimulate the orderly arrangement of collagen fibers and promote tendon remodeling. Patients with knee osteoarthritis can strengthen the quadriceps muscle with centrifugation (such as a slow step-down step) to reduce joint stress and improve function.

Performance enhancement: Athletes use overload centrifugal training (such as cushioning control after jumping) to enhance muscle tension and reduce the risk of sports injury. Power lifters break through the power plateau by deliberately extending the centrifugal phase (such as bench press barbell slowly down) ^[6].

Senile sarcopenia interventions: Low-intensity slow centrifugation exercises (such as controlled standing in a sitting position) can safely improve muscle mass (clinical trials show an 8% increase in leg muscle mass) and function (15% increase in walking speed), while reducing the risk of falls.

3. Physiological mechanism of centrifugal contraction

3.1. Effects of centrifugal contraction on muscle fibers

The physiological effects of centrifugal contraction on muscle fibers are significantly different from other forms of contraction, especially in the type specificity of muscle fibers, damage repair, and hypertrophy mechanism (**Table 1**). The high mechanical tension of centrifugal contraction (up to 1.2–1.4 times that of centripetal contraction) preferentially acts on type II fast muscle fibers, resulting in more pronounced break of the Z-line of the myocyte and microdamage of the myofibril (50% higher damage rate than centripetal contraction), but also triggers a stronger adaptive repair response. For example, after centrifugal training, myosatellite cell activation in type II fibers increased by 40%, while type I fibers increased by only 15%. This selective stimulation is associated with a higher density of myosin heavy chains (MHC-IIx) within type II fibers and a faster cross-bridge cycle rate. In addition, centrifugal contraction promotes net muscle growth by activating the mTORC1 and p70S6K signaling pathways, increasing muscle protein synthesis by 30% (10% higher than centripetal contraction) and inhibiting the activity of the ubiquitin-proteasome system (20% lower MuRF-1 expression) ^[7].

Table 1. Comparison of the effects of eccentric vs. concentric contractions on muscle fibers

Indicator	Eccentric contraction	Concentric contraction	Data source
Type II fiber damage rate	↑35% (after 24 hours)	↑15% (after 24 hours)	Proske <i>et al.</i> , 2001
Satellite cell activation rate	+40%	+20%	Hyldahl <i>et al.</i> , 2017
Muscle protein synthesis rate	+30%	+20%	Moore <i>et al.</i> , 2009
MuRF-1 expression change	↓20%	↔	Murphy <i>et al.</i> , 2020
Type I fiber hypertrophy effect	+8%	+5%	Franchi <i>et al.</i> , 2014

3.2. Effects of centrifugal training on muscle strength and endurance

Centrifugal training significantly increases muscle maximum strength and fatigue resistance through unique biomechanical and metabolic adaptations. Studies have shown that 6 weeks of centrifugal training can increase the maximum isometric strength by 25–35% (only 15–20% for centripetal training), due to the deep activation of high-threshold motor units by centrifugal load (30% higher EMG signal amplitude) and the enhanced storage of tendon elastic potential energy (15% higher energy feedback efficiency). In terms of endurance, centrifugation extends the ability of muscles to work continuously by optimizing mitochondrial function (e.g., cytochrome C oxidase activity ↑20%) and delaying the accumulation of metabolites (12% reduction of peak blood lactic acid). For example, long-distance runners with centrifugal downhill training experienced an 18% increase in exhaustion time, while markers of muscle damage (such as CK) increased only slightly (40% lower than centripetal training).

In addition, centrifugal training has unique advantages for explosive power: the centrifugal phase of drop jump training increases the vertical jump height by 8–12% through increased tendon stiffness (↑10%) and neural drive synchronization (0.1 seconds shorter when reacting) ^[8]. It is worth noting that the effect of centrifugal training is load-dependent: when the centrifugal load exceeds 120% of the centripetal load, the strength gain increases significantly (SMD = 0.78, $P < 0.01$), but strict monitoring is required to avoid excessive damage.

3.3. Neural adaptive response induced by centrifugal training

Centrifugal training significantly improves nervous system fitness by optimizing neuromuscular control and motor unit recruitment strategies (**Table 2**). Centrifugal action requires higher neuroinhibitory regulation to prevent

excessive strain, such as increased sensitivity of the Golgi tendon organ (GTO), resulting in enhanced inhibitory feedback signals (15% reduction in H reflex amplitude), thereby protecting the muscle from acute injury. At the same time, centrifugal training promoted the recruitment of high-threshold motor units (HTMU), whose activation rate increased from 60% to 85% of the baseline level, while centripetal training only reached 70%. This neural adaptation is achieved through plasticity in the upper centers of the spinal cord, such as the motor cortex, and is manifested by a 20% increase in the amplitude of the motor evoked potential (MEP) ^[9].

Table 2. Effects of eccentric vs. concentric training on neural adaptations

Indicator	Eccentric training effect	Concentric training effect	Data source
HTMU recruitment rate	+25%	+10%	Aagaard <i>et al.</i> , 2000
GTO inhibition feedback intensity	↑30%	↔	Nicol <i>et al.</i> , 2003
EMG signal amplitude (Type II)	+35%	+15%	Tesch <i>et al.</i> , 1990
Cortical excitability	+20% (MEP amplitude)	+8% (MEP amplitude)	Contraction, 2011
Neuromuscular efficiency	↑18%	↑5%	Duchateau <i>et al.</i> , 2014

4. Role of centrifugal contraction training in sports rehabilitation

4.1. Rehabilitation application and effect of centrifugal training

Centrifugal contraction training has unique biomechanical and physiological advantages in sports rehabilitation and is widely used in the recovery of tendon injury, osteoarthritis, and muscle strain (**Table 3**). In the case of Achilles tendinitis, progressive centrifugal training (e.g., “Nordic hip brace”) stimulates collagen fiber remodeling by applying controlled tensile stress, and a 12-week intervention can increase Achilles tendon stiffness by 20% and reduce pain scores by 60%. For patients with knee osteoarthritis, centrifugal strengthening of the quadriceps (such as slow step-down exercises) can reduce joint stress (30% reduction in patellofemoral stress) and improve lower limb function (25% increase in 6-minute walking distance). In muscle strain rehabilitation, centrifugal training shortened the recovery cycle by up to 30% by promoting muscle satellite cell activation (40% higher than conventional training) and inhibiting fibrosis (35% lower expression of TGF-β1).

Table 3. Comparison of the effects of eccentric training in different rehabilitation scenarios

Injury type	Intervention plan	Key effects	Data source
Achilles tendinopathy	Nordic hamstring (3×15 reps/week)	Achilles tendon stiffness ↑20%, Pain VAS ↓60%	Silbernagel <i>et al.</i> , 2007
Knee osteoarthritis	Eccentric stair training (2×30 min/week)	Joint pressure ↓30%, WOMAC function score ↑25%	Beyer <i>et al.</i> , 2015
Hamstring strain	Eccentric hamstring training (4×8 reps/week)	Recovery time shortened by 30%, Recurrence rate ↓50%	Askling <i>et al.</i> , 2013
Rotator cuff injury	Eccentric external rotation training (3×12 reps/week)	External rotation strength ↑35%, MRI shows tendon integrity improvement	Sandhu <i>et al.</i> , 2008

Mechanism of action:

Collagen remodeling: Centrifugal load stimulates tendon/ligament fibroblasts to secrete type III collagen

(from 10% to 30%), improving tissue elasticity;

Metabolic regulation: The ischemia-reperfusion cycle promotes angiogenesis (capillary density ↑15%) and accelerates inflammation clearance;

Neuromuscular control: It enhances proprioception (joint position error ↓20%) and motor coordination, reducing the risk of compensatory injury.

4.2. Influence of centrifugal training on rehabilitation of sports injuries

Centrifugal training can significantly improve rehabilitation efficiency by targeted repair of damaged tissues and optimization of functional adaptability. In acute muscle strain, early centrifugation training (within 72 hours after injury) tripled the rate of muscle fiber regeneration by activating satellite cells (50% increase in Pax7+ cell count) and inhibiting fibrosis (40% reduction in collagen deposition). For chronic tendinopathy (e.g., end patellar tendon disease), centrifugation training degrades degenerated collagen by up-regulating the expression of metalloproteinase (MMP-1) (↑200%) and promotes the orderly arrangement of new fibers, resulting in a 45% higher pain relief rate than conventional therapy ^[10].

In the reconstruction of joint stability, centrifugal training is particularly important for ligament repair. After ACL reconstruction, patients who used centrifugal closed-chain training (such as slow centrifugal leg kick) recovered 90% of the quadriceps cross-section area of the affected side to the healthy side after 6 months (only 75% in traditional training), and the dynamic balance test (Y-Balance) score increased by 30%. In addition, centrifugal training reduces secondary injuries caused by compensatory movements (e.g., 60% reduction in contralateral ankle sprains) by enhancing neuroinhibitory feedback (Golgi tendon organ sensitivity ↑25%) ^[11].

Long-term effects:

Prevention of injury recurrence: Centrifugal training reduced the recurrence rate of hamstring strain from 32% to 12%.

Quality of functional recovery: Athletes' time to return to competition after surgery is reduced by 20%, and athletic performance (such as sprint speed) is restored to 95% of pre-injury.

4.3. Practice cases of centrifugal training in athlete recovery

Case 1: A soccer player with a hamstring strain

A professional football player suffered a Grade II hamstring strain during a game (MRI revealed a 30% rupture of muscle fibers). The rehabilitation team designed the centrifuge training program:

Phase 1 (0–2 weeks): Isometric contraction + low-load centrifugation (30% 1RM, 3-second centrifugation/time) with the goal of pain relief (VAS score decreased from 7 to 3);

Stage 2 (3–6 weeks): Progressive centrifugal load (50–80% 1RM, Nordic hip support 3×10 times/week), muscle strength recovered to 85% of the healthy side;

Stage 3 (7–12 weeks): Functional centrifuge training (e.g., high-speed centrifuge treadmill training), return to competition after achieving the agility test.

Results: The total recovery time was 10 weeks (14 weeks for the traditional program), and there was no recurrence in the season after the comeback, and the sprint speed was maintained at 11.2 m/s (11.5 m/s before the injury).

Case 2: Achilles tendinitis in marathon runners

A long-distance runner was sidelined for three months with Achilles tendinitis. Using centrifugal training

combined with biofeedback:

Intervention regimen: Three sets of Nordic hip stiffness daily (load gradually increased from 50% to 120% of body weight), simultaneous monitoring of Achilles tendon strain (ultrasound elastography).

Results: After 8 weeks, the elastic modulus of the Achilles tendon increased from 12 kPa to 18 kPa (normal range: 15–20 kPa), and the pain disappeared completely.

Return to training: Gradually introduce centrifugal downhill running (grade -5%, 2 times a week), and complete the whole horse after 6 months (3h10m, 5 minutes slower than PB) ^[12].

Case 3: Rotator cuff injury in a basketball player

Athletes receiving conservative treatment for partial rotator cuff tear:

Centrifugal training: Lateral rotation (dumbbell slowly lowered, 4×12 times/week), combined with PNF stretching;

Progress: After 6 weeks, the external shoulder rotation torque increased from 15 Nm to 28 Nm (healthy side 30 Nm), and MRI showed collagen filling in the torn area.

Functional recovery: Return to dunk training after 8 weeks, return to competition after 12 weeks, shoulder stability test (Kerlan-Jobe) score of 92/100.

Summary: Centrifugal training achieves efficient tissue repair and functional reconstruction in athlete rehabilitation through precise load regulation and stage progression, and its success depends on personalized program design and multidisciplinary collaboration (sports medicine, biomechanics, nutritional support).

5. Implementation and evaluation of centrifugal contraction training

5.1. Implementation strategy of centrifugal contraction training

The implementation of centrifugal contraction training should be based on the principle of individuation, combining the movement goal, the functional baseline, and the risk of injury. Healthy people can use overload centrifugal training (such as the slow down stage of barbell bench press, the centrifugal load is 120% centripetal), 3–5 times per group, 2–3 times per week, to maximize the muscle hypertrophic effect; Recovering patients (e.g., Achilles tendinitis) require progressive loading (from 30% to 100% of body weight) combined with isometric contractions (e.g., centrifugal-isometric training) to avoid acute injury. Elderly or frail people are recommended to use low-intensity slow centrifugation (such as sitting and standing control, centrifugation time extended to 5 seconds), combined with balance training to improve functional fitness. In the training design, the technical points include:

Action control: Emphasize the whole tension of the centrifugal stage (such as keeping the dumbbell down for 3–4 seconds);

Auxiliary equipment: Use skateboards, elastic bands, or centrifugal trainers to reduce joint impact;

Advanced strategy: Increase the load by 5–10% every 2 weeks or extend the centrifugation time by 1 second to ensure adaptive stimulation.

5.2. Evaluation criteria and effects of centrifugal training

The effect of centrifugal training should be evaluated by multi-dimensional indicators:

Muscle strength: Isokinetic muscle strength test (such as knee extension moment increase $\geq 20\%$ is effective);

Functional recovery: Functional motor testing (such as a 15% increase in one-leg jump distance or a

1.5-second reduction in TUG test time);

Structural improvement: Ultrasound or MRI assessment of tendon/muscle cross-sectional area (e.g., an increase of $\geq 10\%$ in Achilles tendon thickness);

Biomarkers: Serum CK levels (monitoring microdamage) and IL-6 (inflammation control).

Effectiveness verification: Clinical trials have shown that 12 weeks of centrifugal training can increase the peak centrifugal moment of the hamstring muscle by 35% (vs. centripetal training 20%), and the walking speed of the elderly group increased by 0.2 m/s ($P < 0.05$)^[13]. Combined with surface electromyography (sEMG), the efficiency of nerve drive can be quantified (e.g., a 25% increase in type II fiber activation).

5.3. Safety and risk management in centrifugal contraction training

The high mechanical tension characteristics of centrifugal training require strict safety management:

Risk identification: Common risks include delayed onset muscle soreness (DOMS, 70%), tendon strain (especially overtraining), and joint stress accumulation (such as excessive knee flexion Angle causing cartilage wear).

Prevention strategies:

Load monitoring: $\leq 60\%$ 1RM in the initial stage, gradually increasing.

Movement standardization: Avoid rapid centrifugation (such as free weight uncontrolled lowering), use instruments to lock the safe range.

Recovery management: Cold therapy (to reduce inflammation) and dynamic stretching (to improve blood flow) within 48 hours after training.

Special population intervention: Osteoporosis patients avoid high-impact centrifugation (such as deep jump), and use water centrifugation training. Patients with cardiovascular disease need to monitor their blood pressure (to avoid Valsalva reaction). Real-time monitoring of motion quality through biofeedback devices, such as inertial sensors, can reduce the risk of injury by more than 30%^[14].

Disclosure statement

The author declares no conflict of interest.

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Epidemiological Characteristics and Influencing Factors of Flatfoot among Primary and Middle School Students in Inner Mongolia

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Abstract: *Objective:* To analyze the epidemiological characteristics and influencing factors of flatfoot among primary and middle school students in Inner Mongolia. *Methods:* A survey was conducted among 2,800 primary and middle school students in Inner Mongolia. The foot arch and plantar pressure of the subjects were measured using the footprint method and the FootcanUSB plantar pressure testing system, respectively. The incidence of flatfoot among primary and middle school students was statistically analyzed, and regression analysis was used to analyze the influencing factors of flatfoot occurrence. *Results:* Among the 2,800 students, 867 cases of flatfoot were detected, with a detection rate of 30.95%. The proportions of mild, moderate, and severe flatfoot were 21.12%, 46.23%, and 31.62%, respectively. The detection rates of flatfoot among males and females were 20.04% and 10.93%, respectively, with the male detection rate significantly higher than that of females ($P < 0.05$). The detection rates of flatfoot among students aged 7 to 14 years old were 49.42%, 42.18%, 40.34%, 35.78%, 28.49%, 23.33%, 15.79%, and 11.95%, respectively. The detection rates of flatfoot varied among students of different ages, and the detection rate gradually decreased with increasing age. Weight, household registration, extracurricular activities, and shoe type were all influencing factors of flatfoot occurrence among primary and middle school students, in addition to BMI and physical exercise ($P < 0.05$). The risk and protective factors for flatfoot occurrence among primary and middle school students were BMI and physical exercise, respectively ($P < 0.05$). *Conclusion:* The incidence of flatfoot is relatively high among primary and middle school students in Inner Mongolia. Relevant factors for the occurrence of flatfoot include weight, household registration, and physical exercise. To reduce the occurrence of flatfoot, it is recommended to control weight and engage in regular physical exercise.

Keywords: Flatfoot; Students; Incidence; Influencing factors

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1. Introduction

As a common orthopedic foot deformity, flatfoot mostly refers to the collapse or absence of the medial longitudinal

arch of the foot. Its occurrence can affect the overall gait and lower extremity force, which can not only cause muscle pain but also result in abnormal gait^[1]. The occurrence of flatfoot is not only related to congenital factors such as laxity of the plantar ligaments or tendons and equinovarus deformity, but also to the insufficient development of tendon strength caused by lack of physical exercise^[2]. Flatfoot can cause abnormal biomechanical parameters, which can not only cause pain and lead to mechanical imbalance but also result in foot dysfunction and lead to overuse injuries of the lower extremities. The incidence of flatfoot is relatively high among young children and adolescents. Scientific examination and intervention can correct the gait of patients with flatfoot and prevent related foot diseases^[3]. Based on this, this study selected 2,800 primary and middle school students in Inner Mongolia for investigation to analyze the epidemiological characteristics and influencing factors of flatfoot among primary and middle school students in Inner Mongolia, providing a basis for the prevention and treatment of flatfoot.

2. Subjects and methods

2.1. Research subjects

A survey was conducted among 2,800 primary and middle school students in Inner Mongolia. The students were randomly selected with a 1:1 ratio of males to females, aged between 7 and 14 years old. Students with a history of surgery, trauma, or severe diseases were excluded.

2.2. Methods

2.2.1. Survey questionnaire

The survey questionnaire included basic information, as well as questions about physical exercise, study and extracurricular activity time, shoe type, eating habits, and household registration type. Body mass index (BMI) was also calculated.

2.2.2. Arch and plantar pressure testing

The foot arch and plantar pressure of the subjects were measured using the footprint method and the FootcanUSB plantar pressure testing system, respectively. For foot arch measurement, students were asked to step on a piece of paper soaked in 10% potassium ferrocyanide solution and then dried, after stepping on a gauze soaked in 10% ferric chloride solution. This would leave a blue-black footprint on the paper, and the area of contact between the student's feet and the ground was calculated. For plantar pressure testing, students were asked to walk barefoot on a force plate placed on a flat surface. After walking at a normal pace three times, the collected data was analyzed.

2.3. Statistical methods

SPSS 22.0 statistical software was used for analysis. Measurement data and count data (relative numbers) were tested using *t* and chi-square tests, respectively. Logistic regression analysis was used for multifactor analysis. A *P*-value less than 0.05 was considered statistically significant.

3. Results

3.1. Detection rate of flatfoot and related factors

Among the 2,800 students, 867 cases of flatfoot were detected, with a detection rate of 30.95%. Among them, there

were 185, 405, and 277 cases of mild, moderate, and severe flatfoot, accounting for 21.12%, 46.23%, and 31.62%, respectively. The detection rates of flatfoot among males and females were 20.04% and 10.93%, respectively, with the male detection rate significantly higher than that of females ($P < 0.05$).

3.2. Detection rate of flatfoot

The detection rates of flatfoot among students aged 7 to 14 years old were 49.42%, 42.18%, 40.34%, 35.78%, 28.49%, 23.33%, 15.79%, and 11.95%, respectively. The detection rates varied among students of different ages, and the detection rate gradually decreased with increasing age. See **Table 1** for details.

Table 1. Detection rate of flatfoot among students of different ages

Age (years)	Number of cases	Number of detected cases	Detection rate (%)
7	346	171	49.42
8	358	151	42.18
9	352	142	40.34
10	341	122	35.78
11	358	102	28.49
12	360	84	23.33
13	342	54	15.79
14	343	41	11.95

3.3. Single-factor analysis of flatfoot among primary and middle school students

Weight, household registration, extracurricular activities, and shoe type were all influencing factors for the occurrence of flatfoot among primary and middle school students. Additionally, BMI and physical exercise were also included ($P < 0.05$). See **Tables 2** and **3** for details.

Table 2. Assignment of categorical variables

Variables	Assignment
Gender	Male = 1, Female = 2
Household registration type	Rural = 1, Urban = 2
Physical exercise	None = 1, Occasional = 2, Regular = 3
Study time (per day)	< 6 = 1, 6–8h = 2, > 8h = 3
Extracurricular activity time	< 2 = 1, 2–4h = 2, > 4h = 3
Eating habits	Poor = 1, Good = 2
Type of shoes worn	Appropriate shoes = 1, Inappropriate shoes = 2
BMI	Underweight = 1, Overweight = 2, Normal = 3

Table 3. Single-factor analysis of influencing factors for flatfoot among primary and middle school students

Variables	β	SE	Wold	<i>P</i>	OR	95% CI
Age	0.152	0.953	1.652	0.103	1.162	0.892–1.452
Gender	-0.151	0.532	0.024	0.783	0.895	0.457–1.844
Height	0.107	0.881	0.038	0.863	1.002	0.864–1.046
Weight	0.326	0.231	16.242	0.000	1.253	1.143–1.642
BMI	0.564	0.363	19.024	0.000	1.674	1.342–2.153
Household registration type	0.806	0.214	5.633	0.023	2.235	1.113–4.634
Physical exercise	-0.786	0.764	4.532	0.048	0.452	0.212–0.956
Study time	0.542	0.412	2.173	0.076	1.673	0.864–3.324
Extracurricular activity time	-0.673	0.684	8.533	0.043	0.467	0.231–0.986
Eating habits	-0.563	0.401	3.165	0.063	0.487	0.231–1.223
Type of shoes worn	0.476	0.613	4.756	0.031	1.542	1.021–2.673

3.4. Multifactor analysis of influencing factors for flatfoot among primary and middle school students

The risk and protective factors for the occurrence of flatfoot among primary and middle school students were BMI and physical exercise, respectively ($P < 0.05$). See **Table 4** for the results of the multifactor analysis.

Table 4. Multifactor analysis of influencing factors for flatfoot among primary and middle school students

Variables	β	SE	Wold	<i>P</i>	OR	95% CI
BMI	1.574	0.874	17.434	0.000	1.785	1.587–2.431
Physical exercise	-0.689	0.518	21.245	0.000	0.147	0.021–0.342

4. Discussion

Flatfoot is a foot deformity disease characterized by a low and flat foot arch, hindfoot valgus, and forefoot abduction. The occurrence of flatfoot in children is not only related to tarsal joint problems but also associated with neuromuscular diseases^[4]. The medial arch of the foot bears greater pressure due to the abnormal biomechanical line caused by flatfoot. If this condition persists for a long time, it can not only damage the foot but also cause lower extremity injuries. For children with flexible flatfoot, they are usually asymptomatic, and no intervention measures may be necessary. However, some scholars believe that early intervention measures should be taken for children with flatfoot to avoid later foot complications and potential impacts on adulthood^[5]. Flatfoot not only affects foot function but also impacts the quality of life of patients. The results of this study showed that among 2,800 students in Inner Mongolia, 867 cases of flatfoot were detected, with a detection rate of 30.95%. The detection rate in males was significantly higher than in females, which is consistent with the research results of Liu *et al.*^[6]. Among them, there were 185, 405, and 277 cases of mild, moderate, and severe flatfoot, accounting for 21.12%, 46.23%, and 31.62%, respectively. This indicates that the incidence of flatfoot among primary and middle school students in Inner Mongolia is relatively high, with gender differences, and the proportion of moderate and severe flatfoot is relatively high.

Research has shown that the occurrence of flatfoot is related to age^[2]. Childhood is an important period for the development of the foot arch. Due to the low and flat foot arch, the human body is in an abnormal biomechanical environment for a long time, and the plantar pressure cannot be evenly distributed, which can cause foot lesions and lower extremity complications such as medial tibial stress syndrome. The results of this study showed that the detection rates of flatfoot among students aged 7 to 14 years old were 49.42%, 42.18%, 40.34%, 35.78%, 28.49%, 23.33%, 15.79%, and 11.95%, respectively. The detection rates of flatfoot vary among students of different ages, and the detection rate gradually decreases with age, which is consistent with the research results of Zhang *et al.*^[7]. The risk and protective factors for flatfoot among primary and middle school students are BMI and physical exercise, respectively. Plantar pressure can increase with increasing BMI or body weight, which can affect the foot arch and lead to flatfoot. Therefore, it is necessary to pay attention to students' diet and exercise, control their weight within a normal range, and prevent the occurrence of flatfoot^[8]. Physical exercise plays a good role in preventing and improving flatfoot. It can not only enhance ligament strength but also improve foot muscle strength, enhance the ability to maintain the foot arch structure, prevent foot arch collapse or disappearance, and reduce the occurrence of flatfoot^[9].

5. Conclusion

In summary, the prevalence of flatfoot among primary and middle school students in Inner Mongolia is relatively high, and the situation is relatively serious. Relevant factors for the occurrence of flatfoot among primary and middle school students include weight, physical exercise, etc. Therefore, it is necessary to pay attention to students' diet and exercise, control their weight within a normal range, and strengthen physical exercise to reduce the occurrence of flatfoot.

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Disclosure statement

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Clinical Efficacy of Gujian Powder Combined with Shockwave in the Treatment of Early Osteonecrosis of the Femoral Head

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Abstract: *Objective:* To observe the clinical efficacy of Gujian powder combined with extracorporeal shockwave therapy for early osteonecrosis of the femoral head (ONFH). *Methods:* Sixty patients with early ONFH were selected and randomly divided into three groups, with 20 cases in each group. The experimental group was treated with oral gujian powder combined with extracorporeal shockwave therapy. Control group A was treated with gujian powder orally, while control group B was treated with Xianling Gubao capsules orally. *Result:* Compared with before treatment, the VAS score, Harris score, and bone density of the experimental group and control groups A and B were significantly improved at 30, 90, and 180 days after treatment, with statistically significant differences. Compared with the control groups A and B, the experimental group showed more significant improvements in VAS score, Harris score, and bone density at 30, 90, and 180 days after treatment, with statistically significant differences. *Conclusion:* The combination of gujian powder and extracorporeal shockwave therapy significantly improves VAS score, Harris score, and bone density in patients with early osteonecrosis of the femoral head, effectively reduces pain, and improves patient quality of life. Thus, it is worth promoting in the clinics.

Keywords: Traditional Chinese medicine; gujian powder; Extracorporeal shockwave; Femoral head necrosis

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1. Introduction

Osteonecrosis of the femoral head (ONFH) is a difficult-to-treat disease caused by the interruption of blood supply to the proximal femur, which leads to the death of bone cells, affects the body's self-repair, and ultimately leads to structural changes of the femoral head. According to the epidemiological survey, the number of patients with ONFH in China has exceeded 8.15 million^[1], and its prevalence has been increasing year by year, primarily affecting young and middle-aged patients. This disease is treated with artificial prosthesis in the late stage, which has the disadvantage of long-term usage, so preventing and controlling it effectively in the early stage is the key

direction in this field. Study ^[2] found that traditional Chinese medicine and shockwave can effectively improve symptoms in the early treatment of ONFH. Based on this, this study combines the two to observe the efficacy of gujian powder combined with extracorporeal shockwave on early ONFH, which was created by Prof. Wei Guikang, a master of national medicine.

2. Information and methods

2.1. General information

A total of 60 patients with ONFH in Ruikang Hospital of Guangxi University of Traditional Chinese Medicine were included in this study and randomly divided into three groups according to the random number method: gujian powder combined with extracorporeal shockwave in the experimental group; gujian powder alone in control group A, and Xianling Gubao capsules in control group B, 20 cases in each group.

2.2. Inclusion criteria

(1) Western medical diagnosis in accordance with the “Chinese Adults with Osteonecrosis of the Femoral Head Clinical Diagnosis and Treatment Guidelines” standard ^[3]; Chinese medicine diagnosis in accordance with the “Chinese Medicine Diagnosis and Treatment Criteria” ^[4] in the “bone erosion” standard; (2) Ficat stage I, II; (3) Hip joint activity limitation, hip pain; (4) No mental, speech, hearing-related diseases; (5) Understand and be informed of the study and be able to provide complete information.

2.3. Exclusion criteria

(1) Hip dysplasia; (2) Cardiac, hepatic, and renal pathologies, coagulation disorders; (3) History of alcoholism, drug dependence; (4) Pregnancy or lactation.

2.4. Methodology

2.4.1. Experimental group

gujian powder combined with extracorporeal shockwave therapy. gujian powder: Deer antler 100 g, *Cistanche* 200 g, American ginseng 100 g, *Panax ginseng* 100 g, jackfruit 200 g, *Cornus officinalis* 100 g, *Pericarpium Citri Reticulatae* 100 g, *Litsea cubeba* 200 g. These ingredients were crushed and made into pills using honey as a binder. Each pill weighs 1.5 g, and the dosage is 3–5 pills taken 2–3 times daily. One course of treatment lasts for 30 days, and a total of six courses were administered.

Extracorporeal shockwave therapy (ESWT): The ESWT device used was the LGT-2510B model from Guangdong Longzhijie Medical Devices Co., Ltd. Under fluoroscopic guidance, the necrotic area was identified and marked on the body surface, carefully avoiding arterial and venous vessels as well as peripheral nerves. Two to four treatment points were selected. Therapy was initiated with low-energy settings and gradually progressed to higher energy levels, depending on the patient’s pain tolerance. Each session involved 2,400 shocks, administered every two days at a frequency of twice per week. Each course of treatment lasted 30 days, with a total of six courses completed.

2.4.2. Control group A

gujian powder was taken internally, the same as the experimental group.

2.4.3. Control group B

Patients were given oral Xianling Gubao capsules (National Drug License Z20025337 produced by National Pharmaceutical Group Tongjitang [Guizhou] Pharmaceutical Co., Ltd.), 3 capsules each time, 2 times a day. One course of treatment lasts for 30 days, and a total of six courses were administered.

2.5. Observation indexes

VAS score: VAS score was used as the index of pain degree, and the pain was 0–10 points from mild to severe, 0 points for no pain, 1–3 points for mild pain, 4–6 points for moderate pain, and 7–10 points for severe pain.

Harris score: Harris score was used as the patient's hip joint function index, scoring from pain, function, limb deformity, and joint mobility, with a total score of 0–100.

Bone mineral density: Bone densitometer (Qisheng Medical Devices Co., Ltd.) was used to measure the femoral neck, femoral trochanter, and Ward's triangle of the affected side of the hip before, 30d, 90d, and 180d after treatment.

Efficacy criteria: Efficacy was evaluated according to the Expert Consensus on Diagnostic and Treatment Criteria for Adult Femoral Head Necrosis, a combination of imaging and clinical scoring of hip function was adopted, with a ratio of 4:6. Significantly effective: total score ≥ 90 points; effective: total score 70–89 points; ineffective: total score < 70 points.

2.6. Data management and statistical analysis

SPSS 20.0 statistical software was used to analyze the data, the count data were tested by chi-square; the measurement data were expressed as mean \pm standard deviation (SD), and the *t*-test was used; the comparison of multi-group data conformed to the normal distribution with ANOVA; the non-normal distribution was tested by rank sum. When $P < 0.05$, the difference was statistically significant.

3. Results

3.1. Comparison of general information

During the process, one patient in group B was withdrawn. Gender and staging were tested by chi-square tests, and age was analyzed by one-way ANOVA. Comprehensive baseline information (see **Table 1**) of the three groups showed that the difference was not statistically significant ($P > 0.05$), and the three groups of patients were comparable.

Table 1. Baseline information

Indicators	Experimental group (<i>n</i> = 20)	Control group A (<i>n</i> = 20)	Control group B (<i>n</i> = 19)	Statistical value	<i>P</i> value
Gender (cases, male/female)	11/9	8/12	13/6	$\chi^2 = 3.178$	0.204
Age (years, \pm SD)	40.45 \pm 7.48	40.35 \pm 6.69	41.05 \pm 8.14	$F = 0.04$	0.959
Staging (phase, I/II)	12/8	13/7	9/10	$\chi^2 = 1.310$	0.519

3.2. Comparison of VAS scores

Analyzed by repeated measures ANOVA, Mauchly's sphericity test $P = 0.047 < 0.05$ did not satisfy the sphericity test, and based on the results obtained by the multivariate ANOVA test (**Table 2**), the difference was statistically

significant ($P < 0.05$).

Table 2. VAS scores (points, mean \pm SD)

Group	<i>n</i>	Before treatment	Treatment 30d	Treatment 90d	Treatment 180d
Experimental group	20	5.00 \pm 1.02	3.10 \pm 0.91	1.85 \pm 0.67	1.50 \pm 0.68
Control group A	20	4.85 \pm 1.26	4.20 \pm 1.28	2.95 \pm 0.88	2.35 \pm 0.67
Control group B	19	4.89 \pm 0.93	3.89 \pm 1.44	3.16 \pm 0.68	2.63 \pm 0.49
<i>F</i> value	-	0.10	4.251	17.048	17.403
<i>P</i> value	-	0.905	0.019	0.000	0.000

$F_{\text{time}} = 100.38$, $P = 0.000$; $F_{\text{group}} = 14.524$, $P = 0.000$; $F_{\text{alternately}} = 108.000$, $P = 0.018$

3.3. Harris scores

Data were analyzed by repeated measures ANOVA. Mauchly's test of sphericity $P = 0.158 > 0.05$ satisfies the test of sphericity, and the difference was statistically significant ($P < 0.05$) by the within-subjects effect test (**Table 3**).

Table 3. Harris scores (points, mean \pm SD)

Group	<i>n</i>	Before treatment	Treatment 30d	Treatment 90d	Treatment 180d
Experimental group	20	62.25 \pm 4.87	72.60 \pm 4.60	79.75 \pm 5.78	84.90 \pm 5.95
Control group A	20	64.30 \pm 4.93	69.85 \pm 4.70	74.60 \pm 7.30	78.80 \pm 8.95
Control group B	19	63.21 \pm 4.31	70.16 \pm 5.76	73.05 \pm 8.30	76.58 \pm 8.95
<i>F</i> value	-	0.943	1.778	4.688	5.613
<i>P</i> value	-	0.395	0.178	0.013	0.006

$F_{\text{time}} = 69.558$, $P = 0.000$; $F_{\text{group}} = 11.323$, $P = 0.000$; $F_{\text{alternately}} = 2.382$, $P = 0.036$

3.4. Bone density

Data were analyzed by repeated measures ANOVA. Mauchly's sphericity test $P_{\text{femoral neck}} = 0.169 > 0.05$, $P_{\text{Ward's triangle}} = 0.272 > 0.05$ satisfy the test of sphericity, and the within-subjects effect test was used (**Tables 4 to 6**); and the $P_{\text{femoral trochanter}} = 0.001 < 0.05$ was used for multivariate testing. The difference was statistically significant ($P < 0.05$).

Table 4. Bone density of femoral neck (g/cm², mean \pm SD)

Group	<i>n</i>	Before treatment	Treatment 30d	Treatment 90d	Treatment 180d
Experimental group	20	0.609 \pm 0.025	0.630 \pm 0.018	0.645 \pm 0.027	0.669 \pm 0.013
Control group A	20	0.612 \pm 0.020	0.619 \pm 0.016	0.641 \pm 0.029	0.644 \pm 0.028
Control group B	19	0.615 \pm 0.030	0.621 \pm 0.014	0.629 \pm 0.027	0.641 \pm 0.022
<i>F</i> value	-	0.215	2.526	1.6838	9.472
<i>P</i> value	-	0.807	0.089	0.195	0.000

$F_{\text{time}} = 31.741$, $P = 0.000$; $F_{\text{group}} = 5.607$, $P = 0.000$; $F_{\text{alternately}} = 2.263$, $P = 0.045$

Table 5. Bone density of femoral trochanter (g/cm2, mean \pm SD)

Group	<i>n</i>	Before treatment	Treatment 30d	Treatment 90d	Treatment 180d
Experimental group	20	0.510 \pm 0.011	0.526 \pm 0.018	0.537 \pm 0.024	0.560 \pm 0.042
Control group A	20	0.516 \pm 0.016	0.519 \pm 0.025	0.529 \pm 0.023	0.530 \pm 0.031
Control group B	19	0.514 \pm 0.020	0.522 \pm 0.017	0.524 \pm 0.018	0.527 \pm 0.026
<i>F</i> value	-	0.714	0.624	1.648	5.534
<i>P</i> value	-	0.294	0.540	0.202	0.006

$F_{\text{time}} = 54.000, P = 0.000; F_{\text{group}} = 5.854, P = 0.005; F_{\text{alternately}} = 108.00, P = 0.029$

Table 6. Bone density in Ward's triangle (g/cm2, mean \pm SD)

Group	<i>n</i>	Before treatment	Treatment 30d	Treatment 90d	Treatment 180d
Experimental group	20	0.401 \pm 0.149	0.419 \pm 0.017	0.433 \pm 0.019	0.455 \pm 0.029
Control group A	20	0.403 \pm 0.020	0.407 \pm 0.016	0.418 \pm 0.023	0.428 \pm 0.021
Control group B	19	0.402 \pm 0.014	0.413 \pm 0.018	0.416 \pm 0.023	0.422 \pm 0.020
<i>F</i> value	-	0.215	2.526	1.6838	9.472
<i>P</i> value	-	0.807	0.089	0.195	0.000

$F_{\text{time}} = 30.184, P = 0.000; F_{\text{group}} = 9.227, P = 0.000; F_{\text{alternately}} = 3.026, P = 0.01$

3.5. Efficacy criteria

Table 7 shows the efficacy of treatment in each group.

Table 7. Efficacy of treatment in each group

Group	<i>n</i>	Significantly effective	Effective	Ineffective	Overall effective rate
Experimental group	20	14	5	1	95%
Control group A	20	8	9	3	85%
Control group B	19	6	10	4	80%

4. Discussion

ONFH can be categorized as “bone erosion” in Chinese medicine. In this study, we used the formula gujian powder, which was created by Prof. Wei after decades of medical practice, and it is effective in the treatment of early ONFH. According to Prof. Wei, ONFH is caused by qi stagnation and blood stasis due to insufficiency of the liver and kidney, and the combination of the two leads to the development of ONFH. Insufficient kidney yang leads to a lack of nourishment for the medulla oblongata, causing it to become depleted and the bones to wither. Meanwhile, the liver, which stores blood and governs the tendons as their main source of nourishment, also plays a key role in the regulation of qi and blood. Liver deficiency results in the disruption of this regulation, leading to blood deficiency, qi and blood weakness, inadequate moistening of the organs, and impaired function of the tendons and bones. Consequently, the body becomes susceptible to external pathogens such as wind, cold, and dampness, ultimately resulting in the erosion of the bones. Therefore, Prof. Wei suggested that we should nourish the innate to treat this deficiency, promote menstruation and blood circulation, and resolve blood

stasis and open the veins in order to treat the symptoms. There are eight herbs in gujian powder, deer antler and *Cistanche* are the kingpin herbs, which can nourish the kidney, strengthen the bones, and benefit the essence. According to modern pharmacology, antler velvet contains nearly one hundred chemical components, among which antler velvet polysaccharide and antler velvet polypeptide can improve bone density, promote the activity of osteogenic factors in the body, and prevent osteonecrosis ^[5]. *Cistanche* components can effectively resist bone loss and regulate bone metabolism ^[6]. American ginseng, *Panax ginseng*, jackfruit, and cornelian cherry are used together as ministerial herbs to enhance the efficacy of the two monarchical herbs. American ginseng nourishes yin and tonifies qi, generates fluids and quenches thirst, and its components can enhance immunity, regulate metabolism, and exert anti-inflammatory and antioxidant properties ^[7]. *Panax ginseng* activates blood circulation and removes blood stasis, reduces swelling and relieves pain, and its constituents can strengthen the osteogenic function of the body ^[8]. Jackfruit dispels wind and induces dampness, eliminates blood stasis and detoxifies toxins, and its constituents are analgesic and anti-inflammatory and regulate immunity ^[9]. *Cornus officinalis* tonifies the liver and kidney, and its constituents achieve anti-osteoporosis effects by regulating calcium and activated oxygen, and osteoclast differentiation ^[10]. Chenpi and *Litsea cubeba* are the three medicines. Chenpi regulates qi and strengthens the spleen, helps qi to pass; *Litsea cubeba* disperses cold and removes dampness, warms the middle and relieves pain. The whole formula combines the efficacy of strengthening the tendons and bones, regulating qi and dredging, activating blood circulation and relieving pain.

ESWT is a kind of high-pressure, strong sound wave with a short period and low frequency, which produces different forces at the contact surface of the object in its conduction due to the different medium ^[11]. In the field of ONFH, it has been included in the guidelines as a therapeutic measure because of its simplicity, noninvasiveness, low side effects, and obvious efficacy. Studies on its mechanism of action have shown that ESWT mainly produces effects from mechanomechanics, piezoelectric effect, cavitation effect, sensory closure, etc ^[12]. ESWT, due to its own acoustic wave qualities, comes into contact with bone in conduction and produces stresses that can induce bone formation; and the charge of the receiving site will change accordingly when it is in conduction to promote osteogenesis. In addition, the small bubbles in human tissues expand rapidly due to the change of pressure, and the high heat generated can improve blood circulation; finally, the stimulation of sensory nerves by ESWT will change the local medium, inhibit nociceptive conduction, and relieve pain.

5. Conclusion

In summary, this treatment has good clinical efficacy for early ONFH, and the effect improves with the passage of time, which has a certain delaying effect on the early disease progression. For the young and middle-aged patients, it greatly delays the time node when the disease progresses to the advanced stage and requires surgical treatment, and it provides a therapeutic idea for the prevention and treatment of ONFH in the early stage.

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Disclosure statement

The authors declare no conflict of interest

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