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Article

Research on the prevention of joint and muscle injuries in competitive sports by scientific sports—Table tennis as an example

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Abstract: Table tennis is the most popular sport among all people, which damages every joints of the body to a certain extent, and is an example of scientific sports analysis and popularization. Analyzing the causes of joint and muscle injuries in table tennis and seeking effective preventive measures can not only reduce the incidence of sports injuries, but also ensure that athletes keep a high level of competitive state in high-intensity and long-term training and competition to a certain extent, and prolong their sports life. From two aspects of traditional sports injury prevention measures and the design of a multi-data fusion management rehabilitation robot, the prevention of muscle injury in competitive sports has been studied in depth.

Keywords: scientific sports; joint and muscle injuries; rehabilitation robot

1. Introduction

Table tennis is a common sport in our daily lives. Whether it is a high-level competitive sport or a public recreational activity for the general public, table tennis is a physical and mental exercise, which is suitable for both young and old. The game of table tennis has evolved, and the world of table tennis has developed its skills and tactics. Nowadays, the game has become more demanding: with the increase of speed, the change of rotations, rigidity and flexibility of strength and unpredictable changes, the world's top table tennis players must adapt to the ever-changing table tennis competition through intense training. In this case, the accurate application of skills and tactics is indispensable.

In the event group theory, table tennis is a kind of net-isolated confrontation events, which is mainly driven by aerobic oxidation systems, and has certain physical requirements and higher technical requirements. Table tennis is mainly an upper body sport, especially for the hands holding the racket. For this reason, athletes hold the racket with one arm for a long time, which will lead to more muscle activity of one side arm, thus forming the phenomenon of uncoordinated and unbalanced arms. Long-term unilateral weight training can lead to sports injuries.

Although table tennis injuries are mild compared to other sports, there is still a greater risk of injury during long, intense training sessions. The competitive nature of sports also makes it inevitable to sustain injuries during daily training or informal competition. When a certain degree of injury occurs, the athlete will feel physical pain and psychological frustration, reducing motivation. This can affect training and competition to varying degrees. In addition, even though the athlete has been injured, this can be a prolonged ordeal for the athlete since table tennis sports injuries are generally not so severe that they prevent them from participating in the competition. Therefore, the damage caused by sports injuries to table tennis players cannot be ignored and needs to be taken into account.

In addition to the traditional questionnaires, experience transfer of and other ways to prevent joint muscle injuries in competitive sports. With the development of technology, robotics is developing rapidly. The world robotics field is also undergoing radical changes, with its focus shifting from manufacturing to non-manufacturing, from secondary to primary and tertiary industries. Especially in the rapid development of the medical field, the research of medical robots has become a frontier hot spot in the international robotics field [1]. Rehabilitation robot, as a kind of medical robot that receives worldwide attention, is also one of the key development areas. High-level table tennis players are highly susceptible to injuries to muscles, ligaments, joint capsule, bone, and joint tissues due to factors such as high sports volume. These injuries are mostly compound injuries involving multiple organs and tissues. How to quickly and effectively stop the pain and repair various injuries is an important task in the medical Protection of table tennis sports.

This paper presents an in-depth study on the prevention of muscle loss in competitive sports from two aspects: traditional sports injury prevention measures and the design of a multi-data fusion management rehabilitation robot.

2. Related work

2.1. Sports injury classification and causes

Sports injuries are a variety of injuries that can happen to athletes during daily training or competition. When people are in different sports, there are many different types of injuries that can be sustained. Sports injuries are closely related to the environment of sports, the content of sports training, the mastery of sports techniques, the differences in the types of sports, and even the types of sports equipment. Even the type of sports equipment is closely related.

Fawkner HJ et al. classified acute and chronic sports injuries by the duration of the injury [2]. Rettig AC classified sports injuries into technical and non-technical sports injuries by comparing the correlation between the technical requirements of the training program and the training [3].

Sports injuries are classified into various types. Muscle-based injuries are classified as muscle strain, muscle spasm, muscle contusion, and muscle strain. By joint-based injuries are divided into articular cartilage injuries, arthritis, joint dislocations, and joint sprains. Nerve injuries are classified as peripheral nerve injuries and concussions.

The treatment of sports injuries usually uses treatments such as manual massage and physical therapy assistance. Manual massage is the use of various techniques or simple devices to assist the patient's movement, relieve muscle fatigue, release muscle tension, and restore joint mobility. Physiotherapeutic assistance is the use of electromagnetic-related effects to assist the patient's recovery of the affected limb by means of weak current guidance, hot and cold effects, and magnetic effects. These treatments are done by discrete devices, which require frequent changes of equipment, creating obstacles to the treatment process. In this paper, a unified rehabilitation management system is designed to integrate these discrete therapeutic devices into a single interface, which can bring convenience to physicians in giving physical therapy to patients.

2.2. Sports injuries in table tennis

Pintore and Maffulli [4] pointed out in the article "Osteochondritis dissecans of the lateral condyle of the humerus in table tennis players" that in early training, high-level athletes often have long training time and many repetitive movements, which leads to osteochondritis dissecans of the lateral condyle of the humerus in table tennis players. Ron et al. [5] propose methods for the treatment of simultaneous closed dislocations of the bilateral interphalangeal joints. Dufek et al. [6] described a stress fracture of the ulna in a 26-year-old professional table tennis player in a case report. MRT. This stress fracture was caused by a change in training intensity and a change in the table tennis paddle.

The sports injuries in table tennis were mainly pathologically analyzed, and by combining clinical medicine, sports medicine, and medical imaging, the sites of injuries in table tennis players were thoroughly discussed, and specific pathological findings were presented, which provided valuable experience in the prevention and treatment of sports injuries.

2.3. Robot-assisted sports injury rehabilitation

Despite the differences in human upper limb joints between the shoulder, elbow, wrist, and finger, the control data, control principles, and training modes of upper limb rehabilitation robots studied in various countries are similar. The upper limb rehabilitation robots generally use the sEMG signal from the healthy limb to drive the affected limb for assisted rehabilitation training and record the training data to evaluate the rehabilitation effect and improve the training method. The following is a list of rehabilitation robots designed by different organizations for their upper extremity joints of interest, with a time dimension that shows a gradual improvement in interaction.

Early research began in 1987 when Mike Topping of the United Kingdom developed the Handy1 rehabilitation robot, a 5-degree-of-freedom robot consisting of a robotic arm and a controller that could drive the wrist, elbow, and fingers for active rehabilitation, with voice and data recording capabilities.

In 1991, the first complete upper limb rehabilitation robot was developed at MIT University, named MIT-Manus, as shown in **Figure 1**. In 1995, an American research institute developed the MIT-MANUS brain neurorehabilitation robot, which achieves two- and three-dimensional movements of the shoulder, elbow, and forearm parts through impedance control strategies on the basis of ensuring the smoothness of planar movements, thus stimulating the reconstruction of brain synapses and achieving the effect of brain therapy. The system has been subdivided into four rehabilitation training modes to accommodate different training phases: passive training, active training, booster training, and integrated training [7].

Figure 1. Planar shoulder-and-elbow Module of MIT-MANUS [8].

In recent years, rehabilitation robots have been studied more intensively. 2016, Myomo, a US company, developed a wearable rehabilitation robot based on either two joints, as shown in **Figure 2**. The robot consists of two support parts, each with one degree of freedom, and acquires the patient's EMG through the joint where one of the support parts is located to control the movement of the joint where the other support part is located and movement [9,10].

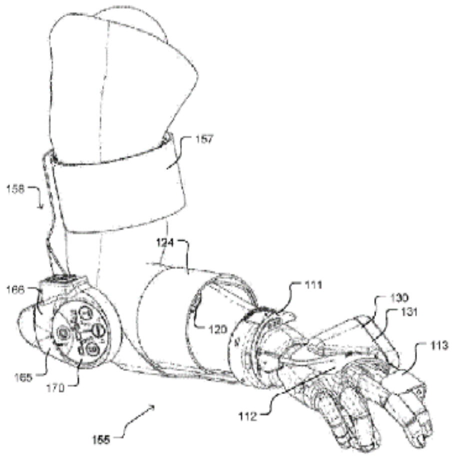


Figure 2. Exoskeleton therapy robot.

3. Research on scientific sports to prevent joint and muscle injuries in competitive sports

3.1. Analysis of the current situation of injuries in high-level table tennis players

In this paper, questionnaires were administered to high-level athletes through an injury questionnaire, and the body parts by injury were classified as head and neck region, trunk region, upper limb region, lower limb region, and other regions (Supplementary). The injury tissues were classified as bone, ligament, joint, muscle, and skin.

The aim of the sports injury questionnaire is to analyze the injury sites with higher incidence and more serious injuries in high-level table tennis players. Among the skeletal tissues, the highest incidence of knee injuries was 25%; among the ligament tissues, the highest incidence of ligament injuries near the calf was 39%; the joint tissues were more dispersed, with the highest incidence of wrist and ankle joints at 39%, followed by knee joints at 36%, hip joints and finger joints at 32%. The highest incidence of sports injuries in muscle tissue was in the hip muscle group with an incidence of 71%, followed by the upper arm muscle group with an incidence of 64%, the shoulder muscle group with an incidence of 57%, and the abdominal muscle group with an incidence of 54%; while the incidence of skin injuries was low and not statistically significant.

3.2. Sports injury prevention policy measures and countermeasures

The key to implementing the necessary preventive measures before and after sports injuries in this subsection is to achieve the most stable, best and comprehensive condition of the athletes; training organization and implementation should be the most reasonable, efficient and targeted. The preventive measures in this stage will be divided into warm-up exercises before training, relaxation exercises after training and rest and daily diet and nutrition when not training.

3.2.1. Must pay attention to the warm-up exercise before training

Reasonable warm-up exercises are divided into general warm-up exercises that can be used in all sports and special warm-up exercises for a particular sports skill. The general warm-up exercises are based on brisk walking, jogging, light weight-bearing exercises and light stretching, which can be arranged before the special warm-up exercises; the special warm-up exercises are different according to the training special, focusing on the joints, ligaments, muscle groups and other parts of the special need to use. Warm-up exercises can improve the function of the body's systems, so that the respiratory system, cardiovascular system, etc. as soon as possible to reach the level required for training, increase pulmonary ventilation and cardiac output. Capillary dilation is conducive to the transport of oxygen in the blood to various organs, the internal organs involved in exercise to obtain more oxygen and reduce physiological inertia. Warm-up exercise also increases body temperature, accelerates cellular metabolism, enhances the rate of nerve conduction, improves the sensitivity of synaptic receptors, and increases the ability to respond and coordinate. Warm-up exercises can reduce the viscosity of the body, so that muscle fibers have higher stretch, fully expand the flexibility of the peripheral ligaments, and reduce the incidence of injury. In addition, a reasonable warm-up improves mental excitability, makes it easier to relax the mind, reduces tension, and allows for better concentration during training, making the technical movements more coordinated and accurate.

Although table tennis is not prone to very serious sports injuries, it is prone to mild and moderate sports injuries in the process of constant strain. If warm-up exercises are neglected and long, high-intensity training is carried out directly, the organism is bound to have difficulty adapting, with ligaments not being fully stretched, muscle fibers not fully elastic, and muscle strength not being ramped up in a gradual manner, the organism is prone to serious sports injuries caused by unexpected situations. In the absence of an adequate warm-up, the nervous system, respiratory system, urinary system, cardiovascular system, etc. are still working in a quiet state, suddenly switch to high-intensity work, will lead to poor breathing, proteinuria, muscle cramps, brain hypoxia and other adverse reactions, very serious and even affect the normal functioning of internal organs and brain, resulting in irreversible permanent damage. Neglecting warm-up exercises not only sows potential damage to body parts, but also makes it difficult to complete the normal training program. Without giving the body a gradual process of entering a working state, it will approach the physical limit more quickly during training, and body fatigue will occur. If you continue to train will cause inattention, the body control ability is not enough to cope with training changes, when the technical movements cannot be completed in accordance with the established requirements, so that the body force way, force direction, etc. is not controlled, and is very easy to cause sports injuries.

3.2.2. Relaxation activities after training must be paid attention to

Relaxation activities are activities that purposefully stretch and shake the tissues involved in exercise, so that the stretched tissues can be fully recovered, relieve fatigue, prevent muscle strain, and maintain the elasticity of muscle fibers. Commonly used relaxation activities include jogging, stretching, physical stimulation, etc. Jogging after exercise when the body tissues in the running natural shock jitter, can make the joints in the shock process to return to normal, so that the muscle fibers in the natural jitter to restore the normal arrangement. Stretching can make the relevant ligaments maintain a certain degree of flexibility and stretching. Static stretching and dynamic stretching are divided into static stretching and dynamic stretching. Static stretching is a slow and gentle stretch that stretches the ligaments, muscle groups, and tendons of nearby joints to a slightly sore level, with a pause of about 15 seconds, followed by a slow relaxation. Dynamic stretching, on the other hand, requires the athlete to perform some specific movements, rhythmically and gradually increasing the pulling strength, using a continuous movement of pulling-relaxing-pulling, completed in groups. Physical stimulation method is the use of special apparatus, such as foam shafts, fascia guns, etc., or let teammates in the training area massage, pedal and other ways to relax. Training load, the body parts will be more or less fatigue phenomenon, excessive fatigue will lead to a decline in tissue ductility.

3.2.3. Regular medical supervision

The statistical results of the Coaches' Questionnaire show that all the surveyed coaches regularly map and count the injury status of athletes, generally through active questioning methods. Regular medical supervision allows coaches to keep an eye on the physical condition of athletes, foresee the occurrence of sports injuries in advance when the hidden problems are at an early stage, and have enough time to study and judge effective prevention and countermeasures, which avoids athletes from continuing training or competition when they are already suffering from injuries or diseases, and delays further deterioration of the athletes' injury sites. Therefore, it is important to regularly ask athletes about their injuries, understand their subjective psychological state, and discuss training programs together, which has a very good effect on the prevention of sports injuries.

3.2.4. Proper application of PRICEMM technology

After the occurrence of a sports injury, the injured person must not be moved under non-essential conditions, and must be treated directly at the scene under adequate braking conditions to avoid aggravating the injury and to provide Protection for the rest of the disposal measures. P is the abbreviation of Protection, meaning that after the occurrence of sports injuries must immediately stop sports, take braking measures to protect the injury site. R is the abbreviation of Rest, meaning rest, requiring the cessation of sports, rest in place. The use of ice packs or freezing sprays to cool the injured area is very effective in the early stages of a sports injury, and can make the ruptured capillaries constrict, reduce capillary bleeding, and prevent redness and swelling of the injured area caused by excessive subcutaneous bleeding. It also effectively numbs the peripheral nerves, delays neurotransmitter transmission, and reduces pain in the injured area. Ice time should be no less than 15 min and no more than 20 min, until the pain is no longer obvious when lightly touching the injury site can be suspended, keep observing whether there is frostbite, about 1 hour after the suspension can repeat the implementation of cooling operation until the swelling of the injury site is no longer expanded or even eliminated, if the swelling of the affected area is not significantly eliminated, it is necessary to continue to repeat the above operation. c represents the English Compression, which means to apply pressure to the injury site. If the injury is open, the compression bandage can also reduce bleeding and prevent the tissue fluid inside the injury site from gathering to form edema. M is the abbreviation of Modalities and Medications, which means physical therapy and medication, and the timely use of physical therapy and medication after an acute sports injury can shorten the course of the disease and achieve better recovery.

3.2.5. Adjustment of training program

It is essential to constantly adjust the training program according to the physiological state of the athletes. In the Coaches' Questionnaire designed for this study, coaches generally believe that sports injuries have a greater impact on the implementation of training programs. Then, for the training program to be implemented properly, injury prevention and reduction must be addressed squarely. After an injury occurs, athletes may deliberately reduce the completion of training movements and may also deliberately reduce their power generation because of the pain in the affected area. If training is not stopped, the injury may further deteriorate, but the training effect is not improved, which forms a vicious circle of "pain—deliberate injury avoidance—poor training". The International Manual of Sports Medicine Practice suggests that the best way to prevent a sports injury is to stop the injury from happening.

3.3. Robot-assisted multi-data fusion for sports injury rehabilitation

The Multi-Data Fusion Management System is a functional implementation of the RJMIP protocol. The multi-data fusion management system uses use case diagrams from user requirements analysis for functional module design and database design. It is presented with a human-machine interface to make the interaction between patients and physicians with the sports injury rehabilitation robot and the physiotherapy treatment device more friendly, and to help verify the correctness of the RJMIP protocol. Its motion module adopts the rehabilitation control method of testing first and training later, featuring one treatment prescription for one patient.

The multi-data fusion management system is closely related to the sports injury rehabilitation robot and thus involves some basic concepts of rehabilitation medicine.

Extension/flexion movement: set the state of the body when standing upright as the body's zero position, the movement from the front of the body away from zero position to the direction of zero position and extension direction is called extension movement; movement from zero position to the front of the body away from zero position is called flexion movement, the angle value of the front of the body away from zero position is recorded as a positive value, and the angle value of the back of the body away from zero position is recorded as a negative value.

Joint mobility: The absolute value of the difference between the maximum flexion angle and the maximum extension angle that the body can reach is called joint mobility.

Extension speed/flexion speed: the speed of the human joint in extension is called extension speed; the speed of the human joint in flexion is called flexion speed.

Extension hold time/flexion hold time: The period of time that a joint remains motionless when it reaches its maximum extension angle and stays there is called extension hold time; the period of time that a joint remains motionless when it reaches its maximum flexion angle and stays there is called flexion hold time.

Draft angle/stretch strength: When the body is in a relaxed state and does a draft movement with the help of an external force, the angle corresponding to the draft trajectory is called the draft angle. The magnitude of the external force is called the draft strength.

Passive movement: The process of the patient completing the corresponding movement with the help of external force. The external force can be mechanical or the assistance of another person/one's healthy limb. When performing passive exercise, the patient keeps the muscles of the limb to be exercised relaxed and uses the external force to perform full range of motion in all directions depending on the condition. This type of exercise is suitable for limb movement dysfunction and can help to relax muscles, traction of contracted tendons and other areas, restore muscle strength and maintain or increase joint mobility.

3.3.1. Active training sports injury rehabilitation control methods

Active training is a rehabilitation exercise process in which the patient's affected limb drives the joint mechanism of the sports injury rehabilitation robot, aiming to prevent muscle atrophy and restore and develop muscle strength. The control of active training is diverse, including isometric training, isotonic training, and isometric training, and the training form is variable. The control used in this project is a single isometric training, and the diverse form consists of traditional isometric training and game training.

With safety as a guideline, the active training program was designed as a rehabilitation control method with active testing followed by active training. The active test is derived by controlling the control information of the rehabilitation robot such as Test Vel Min, Test Vel Max and Test Time. The test speed of each group of the rehabilitation robot motion is calculated by inputting the control information and using the appropriate control algorithm. Within the maximum joint mobility of the affected limb, each group of patients performs flexion and extension movements to the best of their ability at the test speed. The test information from the active test is used to ensure that the training process does not exceed the measured range, thus ensuring the safety of the affected limb during the active training. This ensures the safety of the affected limb during active training. The use of active training can restore the muscle strength of the affected limb. After a certain level of training, the extension and flexion strength can be increased to develop muscle strength.

3.3.2. Passive training sports injury rehabilitation control methods

Passive training consists of a sports injury rehabilitation robot driving the affected limb in a relaxed state, designed to relax spastic muscles and traction on contracted tendons, joint capsules and ligaments. The quantitative results of passive training are reflected in the increase in joint mobility. The main parameters that control passive training are training duration, extension speed, extension hold time, flexion speed, flexion hold time, increased distraction angle, and increased distraction intensity.

3.3.3. System mechanism composition

The hardware of the rehabilitation robot system consists of a joint control part (motion module), a physiotherapy control module (physical therapy module) and a software module (upper computer). The joint control part is realized by the sports injury rehabilitation robot, which has the function of assisting patients' shoulder, elbow, hip and knee joints for rehabilitation training. The physical therapy control module consists of three physical therapy treatment instruments. The software module consists of a computer, which can be called the upper computer.

The joint control part of the sports injury rehabilitation robot mainly consists of mechanisms for upper and lower limb movements, active and passive movements, and movement forces. Each of these mechanisms has undergone strict kinematic and kinetic analysis, and can meet the safety and convenience requirements of the rehabilitation robot. The joint control part of the rehabilitation robot combined by these mechanisms is shown in the **Figure 3**.

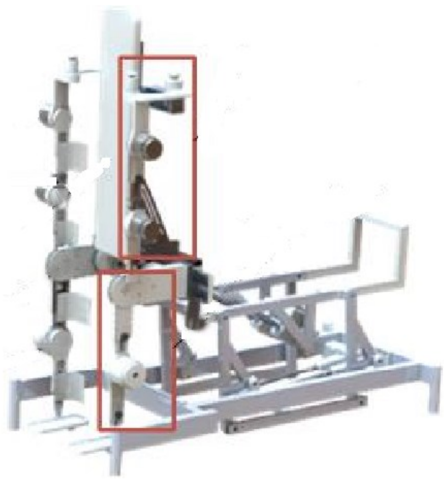


Figure 3. Organization diagram of rehabilitation robot.

The physical therapy module contains three kinds of physical therapy treatment instruments: low-frequency pulse spastic muscle treatment instrument, air pressure wave treatment instrument, and computerized medium-frequency treatment instrument. It can complete the demand of electrotherapy, massage and heat therapy proposed by the rehabilitation robot system.

4. Experiment and analysis

4.1. Data set design

The rehabilitation robot system conceptualizes the information that needs to be stored in the rehabilitation robot by drawing an E-R model. The rehabilitation robot system is composed of a number of different objects and the interrelationships between these objects. These entities are: patient, joint, joint test information, joint training information, low-frequency spasticity muscle therapy device information, air wave therapy device information, computerized intermediate frequency therapy device information, etc. These entities have relatively independent information, so it is necessary to use association table to connect them into a whole with corresponding relationship. This design helps to make the storage clearer, simpler to access, and less redundant.

The Patients Table (**Table 1**) is mainly used to mark user information, and the patient Id number is chosen as the keyword, which is the unique identification of the patient in the database.

Table 1. Patients table.

Name	Class	Data length	Keyword
pID	char	10	Yes
pPassword	char	20	No
pName	char	10	No
pSex	char	2	No
pAge	char	3	No
pHeight	char	3	No
pWeight	char	3	No
pPhone	char	1	No

4.2. Robot-assisted robotic system implementation for sports injuries

The entire rehabilitation robot system consists of a sports injury rehabilitation robot, three physiotherapy treatment instruments, and a multi-data fusion management system. The sports injury rehabilitation robot and the three physiotherapy instruments are the hardware implementations of the multi-data fusion management system.

The multiple training modes of the sports injury rehabilitation robot can assist patients to increase the joint mobility and muscle strength of the affected limb and relieve the pain of the affected limb. The sports injury rehabilitation robot supports passive and active training of shoulder, elbow, hip, and knee joints. The postures of the shoulder joint are internal/external rotation, flexion/extension, and adduction/abduction, and the postures of the elbow, hip, and knee joints are flexion/extension. Passive training can traction contracted tendons, joint capsule and ligaments, which has the therapeutic effect of relaxing spastic muscles, preventing muscle atrophy and relieving pain. Active training can prevent muscle atrophy and achieve the effect of muscle recovery and development. The coupling treatment using sports injury rehabilitation robot and physiotherapy treatment instrument provides a reference pathway for the rapid rehabilitation treatment of patients' joint injuries.

The configuration requirements of the sports injury rehabilitation robot mechanism are the range of motion of the mechanism joints, the speed of the joint motors, and the configuration of sensors that meet the rehabilitation needs. The configuration requirements of the physiotherapy treatment instrument are to be able to provide at least three kinds of therapies: electric therapy, heat therapy, and compression therapy.

The human shoulder, elbow, hip, and knee joints have their specific angles of motion, i.e., joint mobility, as shown in **Tables 2–5** below. The mechanical structure of the sports injury rehabilitation robot should take into account the human body's joint mobility, so as to ensure human safety and achieve the therapeutic effect.

Table 2. Shoulder joint motion angle.

Joint	**Shoulder joint**					
Posture	flexion	extension	abduction	adduction	external rotation	internal rotation
Maximum attitude Angle value	180°	50°	180°	10°	90°	50°

Table 3. Elbow joint motion angle.

Joint	**Elbow joint**					
Posture	external rotation	internal rotation	flexion	extension	posterior rotation	anterior rotation
Maximum attitude Angle value	50°	90°	145°	0°	0°	160°

Table 4. Hip movement angle.

Joint	**Hip**					
Posture	flexion	extension	abduction	adduction	external rotation	internal rotation
Maximum attitude Angle value	120°	10°–20°	45°	10°	45°	45°

Table 5. Knee movement angle.

Joint	**Knee**			
Posture	flexion	extension	external rotation	internal rotation
Maximum attitude Angle value	120°	10°–20°	45°	45°

The posture of interest in this paper is mainly flexion-extension, so the table above is explained in terms of flexion-extension. As shown in **Table 2**, the maximum flexion angle of the shoulder joint is 180°, which means that the human body can move from zero position toward the front of the body to 180°, and the maximum extension angle is 50°, which means that the human shoulder joint can move from zero position toward the back of the body to 50°. Other joint flexion and extension postures are similar. Athletes can use sports injury rehabilitation robot for rehabilitation training and coupled physiotherapy treatment at the same time, so that the rehabilitation effect is better.

4.3. Test analysis

This subsection tests the configuration of a sports injury rehabilitation robot. The main requirements for the mechanism of the sports injury rehabilitation robot are the limitation of the range of joint mobility, the performance of the joint motor speed, and the sensitivity of the sensors. The difference between the angle and strength values of the affected limb during rehabilitation training is 1° and 1N-m, and the patient basically does not feel the change in the size of the two, so the test error of angle and strength values less than 1° and 1N-m meets the rehabilitation requirements.

4.3.1. Test of joint mobility

To test whether the joint mechanism of the sports injury rehabilitation robot meets the rehabilitation requirements. The joint mechanisms tested are: shoulder joint mechanism, elbow joint mechanism, hip joint mechanism and knee joint mechanism. The joint mobility of the joint mechanism should reach the predetermined range and not exceed the set value.

Test whether the maximum flexion angle of each joint mechanism meets the maximum flexion angle setting value. The maximum flexion angle of each joint mechanism is shown in **Table 7**, and the test is performed by sending a command to the maximum flexion angle setting by the multi-data fusion management system and controlling the flexion motion of each joint mechanism from the zero position. When each joint mechanism reaches the maximum flexion angle of its own joint mechanism, the current angle value A is sent back to the MFDMS. After the MFDMS receives the angle value A, it is stored in the MySQL database. The above process is repeated for more than 1000 times. The recorded angle values are analyzed to see if the angle value A of each joint mechanism can reach the maximum flexion angle of each joint mechanism. When the set value is the maximum flexion angle, the joint mechanism should not stop before the maximum flexion angle, but a small error is allowed. For the safety of the patient's limb, the maximum flexion angle should never be exceeded.

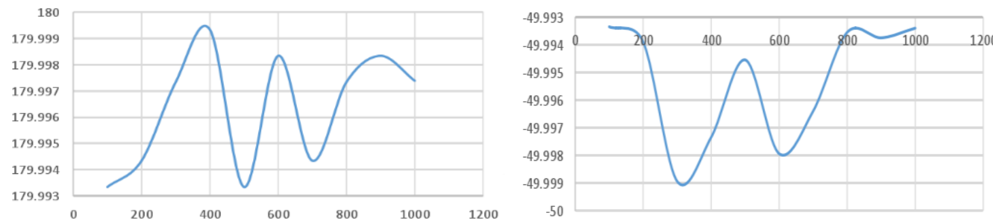
Table 6. Maximum extension angle of flexion-extension posture of sports injury rehabilitation robot.

Joint	Shoulder joint	Elbow joint	Hip joint	Knee joint
Maximum extension angle	−50°	0°	−20°	−120°

Table 7. Maximum flexion angle of flexion-extension posture of sports injury rehabilitation robot.

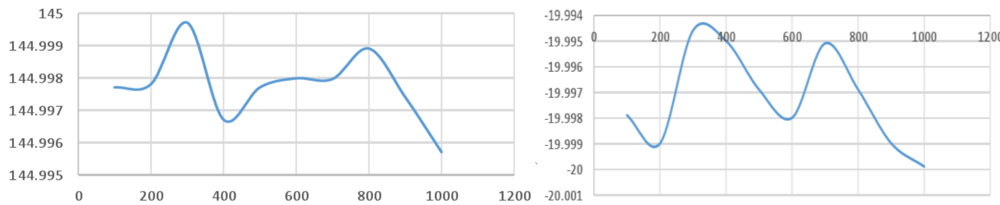
Joint	Shoulder joint	Elbow joint	Hip joint	Knee joint
Maximum flexion angle	180°	145°	90°	0°

Only the maximum joint extension angles of the shoulder, hip and knee joints should be considered for testing, as shown in **Table 6**. Only the maximum joint flexion angles of the shoulder, elbow and hip joints should be considered for testing, as shown in **Table 7**, the maximum flexion angles of the shoulder, elbow, and hip joints are at non-zero position, while the knee joint is at zero position. In this paper, the maximum flexion angle of the joints is tested from the zero position, and it is obvious that the knee joint can reach the zero position, so only the maximum flexion angle and extension angle of the shoulder, elbow and hip joints need to be measured when testing the maximum flexion angle. For each joint to be tested, the maximum flexion angle was tested 1000 times and the maximum extension angle was tested more than 1000 times, and the stability curves were plotted as shown in **Figures 4–6**.



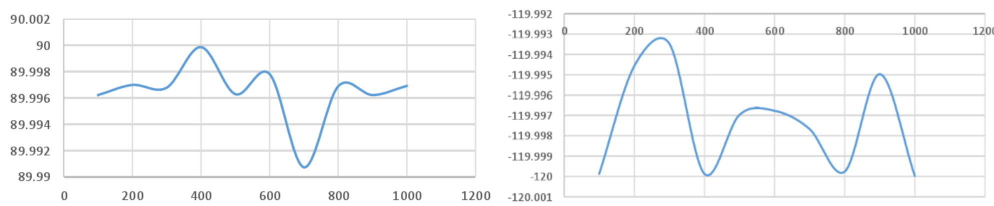
(a) **(b)**

Figure 4. Stability curve of shoulder joint: **(a)** maximum flexion angle; **(b)** maximum extension angle.



(a) **(b)**

Figure 5. Stability curve of elbow joint: **(a)** maximum flexion angle; **(b)** maximum extension angle.



(a) **(b)**

Figure 6. Stability curve of hip joint: **(a)** maximum flexion angle; **(b)** maximum extension angle.

4.3.2. Testing of torque measurement by sensors

The sensor is used to measure the torque level of the patient when using the sports injury rehabilitation robot for rehabilitation training. To a certain extent, the torque size can reflect the muscle resistance or muscle strength of the patient's affected limb, and is an indispensable hardware configuration for sports injury rehabilitation robots.

Torque test principle: the torque of the object can be calculated by placing a certain weight of a square object on the force sensor, and the calculation formula is:

$$T = mg \times L$$

where g is the acceleration of gravity and L is the length perpendicular to the force. The torque calculated by the equation is denoted as T' and the torque measured by using the sensor is denoted as T. T is obtained by reading by the sports injury rehabilitation robot and fed back to the multidata fusion management system and recorded in the MySQL database. t' is directly calculated by the multidata fusion management system and stored in the MySQL database.

Plotting torque error curves. The torque test principle was used for 1000 tests. *T*' and *T*.

T' and *T* from the MySQL database, and calculate $|T - T'|$, thus plotting the torque reliability curve in **Figure 7** as follows.

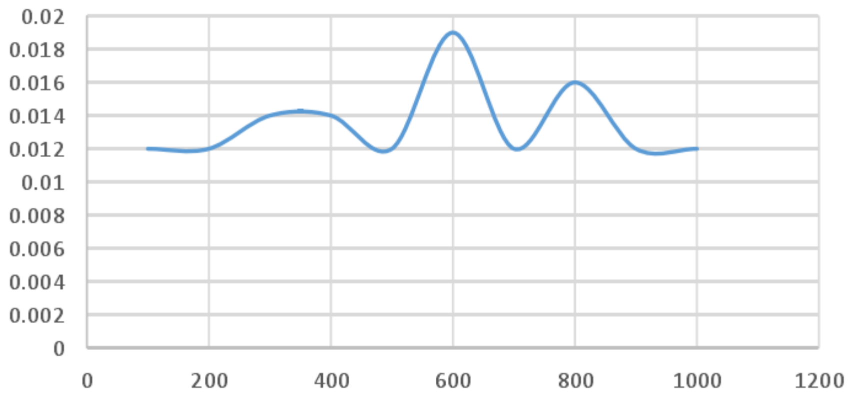


Figure 7. Reliability curve of force sensor torque.

The sensor sensitivity is high, the error is less than 0.02. The error is less than 0.02N-m, the error is relatively small.

5. Conclusion

From two aspects of traditional sports injury prevention measures and the design of a multi-data fusion management rehabilitation robot, the prevention of muscle injury in competitive sports has been studied in depth. A multi-data fusion management system is realized, which can control the rehabilitation robot for sports injuries, and the system can carry out rapid rehabilitation treatment for patients with limbs. The next step could be to study how to combine the database design with big data technology. At present, the amount of data recorded in the database is relatively small. As the increase of data volume, patients' rehabilitation data can be processed based on big data in the later stage, so that personalized prescription and precise treatment can be realized for different joint injuries.

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