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Article

Exploration and Clinical Practice of the Optimization Path of Sports Rehabilitation Technology

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Abstract: With the continuous development of sports rehabilitation technology, the combination of sports science and physical therapy provides patients with personalized and effective rehabilitation plans. However, there are some problems with sports rehabilitation technology in terms of individualized treatment plans and the popularization of equipment. This paper conducts in-depth discussions on these issues and proposes optimization paths, including the optimization of personalized training programs, the innovation and popularization of equipment, as well as the improvement of rehabilitation monitoring and feedback mechanisms. This paper provides an in-depth discussion on the clinical applications of sports rehabilitation in treating sports injuries and elderly patients, as well as implementing personalized rehabilitation interventions, offering theoretical and practical support for future development.

Keywords: sports rehabilitation; physical therapy; sports science; personalized treatment; rehabilitation equipment

1. Introduction

Sports rehabilitation technology combines sports physiology, sports biomechanics and physical therapy. Its main purpose is to help patients restore their physical functions, relieve their pain and improve their living standards. Sports rehabilitation techniques continue to progress, but there are still many problems, such as insufficient individualized treatment, limitations of equipment, and issues of patient compliance. This article focuses on discussing the above-mentioned issues, analyzing the solutions, and exploring how to effectively combine the advantages of sports science and physical therapy to improve the therapeutic effect of sports rehabilitation technology in actual clinical practice. This article also focuses on the application of intelligent technologies and equipment to promote the innovation and development of sports rehabilitation technologies.

2. Theoretical Basis of Sports Rehabilitation Technology

The theoretical basis of sports rehabilitation technology stems from the integration of three disciplines: exercise physiology, exercise biomechanics and physical therapy. Exercise physiology emphasizes the impact of exercise on various systems of the human body. Especially during the rehabilitation process, the intensity, frequency and recovery period of exercise have a significant influence on the degree of adaptation of patients. Sports biomechanics focuses on the study of joint load, muscle movement patterns and force transmission, formulates appropriate exercise plans, avoids sports injuries and improves rehabilitation efficiency [1]. Physical therapy utilizes methods such as heat therapy, electrotherapy and cold therapy to promote blood circulation, alleviate pain, accelerate recovery and enhance the efficiency of rehabilitation. Based on physical therapy, com-

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bined with the application of smart wearable devices, sensors and virtual reality, the accuracy, real-time performance and controllability of sports rehabilitation are ensured to a certain extent, making it scientific and personalized (Figure 1).

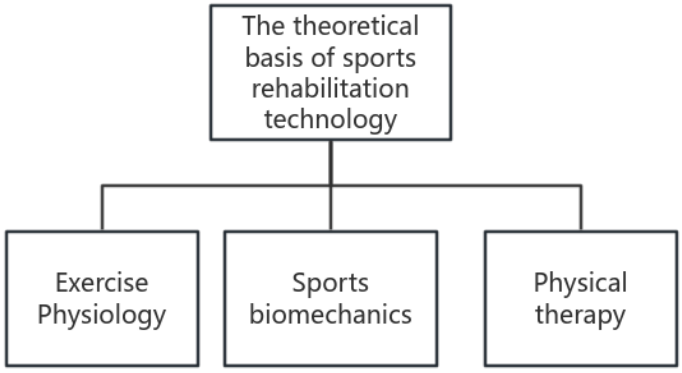

Figure 1. the theoretical framework of sports rehabilitation technology.

3. Application Challenges of Sports Rehabilitation Techniques

3.1. Insufficient Individualization of Sports Rehabilitation Techniques

Although current exercise therapy has achieved remarkable results, a prominent problem is the lack of individualized treatment plans. Traditional rehabilitation treatment plans usually adopt a fixed and universal model, lacking the handling of individual differences such as age, gender, physical constitution, health status and past medical history. The so-called "one-size-fits-all" treatment approach may lead to poor therapeutic effects or aggravate the injury [2]. Because the physical conditions and exercise needs of different patients vary, it is difficult to handle the problem through a unified plan. Excessive exercise or insufficient physical activity may have adverse effects on postoperative recovery, thereby reducing the treatment effect.

3.2. Limitations of Sports Rehabilitation Technology Equipment

Although sports rehabilitation technology equipment has played a significant role in enhancing treatment outcomes and rehabilitation efficiency, the current equipment still has some limitations. Many high-end devices are expensive, which makes it impossible for primary medical institutions and small rehabilitation centers to widely equip them, thus limiting their popularity. The functions of the existing equipment are mostly limited to specific treatment fields and are difficult to meet the diverse rehabilitation needs of patients [3]. Many devices can only provide a single therapeutic function and lack multifunctional integration, thereby reducing their overall clinical utility.

4. Optimization Path of Sports Rehabilitation Technology

4.1. Adjustment and Optimization of Personalized Training Programs

The adjustment and optimization of personalized training plans are important steps in sports rehabilitation. It is aimed at formulating appropriate training plans based on the patient's health condition, motor function and biological response, achieving the best treatment results and improving treatment compliance. Personalized plan design requires the use of detailed exercise assessment data of patients, such as maximum oxygen uptake (VO2max), maximum muscle strength (1RM), joint range of motion, heart rate and other physiological parameters [4]. Based on this, the training intensity, frequency and recovery period of the patients are determined. For example, the calculation formula for the maximum heart rate (HR_{max}) is:

$$HR_{\max} = 220 - \text{Age} \tag{1}$$

The target interval of heart rate (THR) is expressed through the formula:

$$THR = \left(HR_{\max} - HR_{rest}\right) \times \text{Training intensity} + HR_{rest} \tag{2}$$

Among them, HR_{rest} represents the resting heart rate, and the target intensity is set between 50% and 85%. For the quantification of exercise intensity, the commonly used formula is:

$$I = \left(\frac{1RM \times \text{Training percentage}}{100}\right) \tag{3}$$

Through the above formula, therapists can determine the design intensity based on the patient's maximum strength (1RM) and rehabilitation goals to ensure the rationality of the training intensity.

4.2. Innovation and Popularization of Sports Rehabilitation Equipment

The innovation and popularization of sports rehabilitation equipment is the key to optimizing the technical path of sports rehabilitation. Innovative devices, such as smart wearable devices, robot-assisted devices, virtual reality technology, etc., provide more precise and personalized treatment plans for sports rehabilitation. Through integrated design, modern rehabilitation equipment can simultaneously conduct multiple trainings such as strength training, joint recovery and motor coordination, improving treatment efficiency and reducing the treatment time for patients [5]. The application of smart wearable devices and sensors enables therapists to directly obtain patients' movement data, including gait, muscle activity and exercise intensity, so as to adjust treatment plans in a timely manner and reduce patients' excessive or improper exercise. Virtual reality technology can provide patients with an immersive training environment, enhancing their participation and compliance. It is particularly suitable for patients undergoing long-term rehabilitation and experiencing psychological challenges.

4.3. Improve the Rehabilitation Monitoring and Feedback Mechanism

Improving the rehabilitation monitoring and feedback mechanism is an important measure to optimize the technical path of sports rehabilitation. Through smart wearable devices, sensors and motion monitoring instruments, real-time movement data of patients can be obtained, including gait, muscle activity, joint angles and exercise intensity, etc., providing a basis for formulating more scientific and personalized rehabilitation plans [6]. Real-time monitoring technology can assist therapists in adjusting the intensity of training. It can also apply biofeedback technology and virtual reality technology to enhance the treatment effect and increase patients' compliance with the treatment. Biofeedback technology helps patients improve their exercise patterns by monitoring physiological data such as electromyography and heart rate, while virtual reality can provide patients with an interactive and immersive rehabilitation training environment, enhancing the therapeutic effect.

5. Clinical Practical Application of Sports Rehabilitation Techniques

5.1. Physical Therapy and Functional Recovery for Patients with Sports Injuries

Physical therapy and functional recovery for patients with sports injuries play a crucial role in the rehabilitation process. Treatment begins with a detailed assessment to understand the patient's physical condition. Commonly used assessment methods include maximum strength testing (1RM), joint range of motion measurement, and gait analysis. Before treatment, the patient's knee joint flexion and extension angle was 50°, which increased to 80° after rehabilitation training, indicating a clear improvement in joint flexibility. During the acute phase, therapists usually employ cold therapy, electrotherapy and ultrasound therapy to relieve pain, control inflammation and reduce swelling. For in-

stance, after cold compress treatment, the patient's pain score dropped from 7 points before the treatment to 3 points, indicating that the treatment effectively relieved the pain. The pain score is measured by the Visual Analogue Scale (VAS), and a decrease in the score after treatment indicates the therapeutic effect. During the strength training phase, the therapist sets the training intensity based on the patient's 1RM test results. Before treatment, the patient's maximum strength was 30kg. After strength training, the patient's 1RM increased to 50kg, demonstrating a significant improvement in muscle strength. The 1RM test involves gradually increasing the load until the patient can no longer continue the movement, with the maximum successful load recorded as the 1RM. After training, the strength is significantly enhanced. The recovery of joint range of motion was evaluated using joint angle measurement tools. Before treatment, the flexion and extension movement Angle of the knee joint was 50°, and it increased to 80° after treatment, indicating the recovery of joint flexibility. The therapist adjusts the training intensity and joint range of motion based on real-time monitoring data to ensure the gradual recovery of the patient's motor function. Real-time data monitoring and feedback mechanisms play a key role in treatment. Therapists obtain patients' real-time movement data, such as gait, muscle electrical activity and joint range of motion, through smart wearable devices and motion sensors. These data help therapists adjust training programs in real time based on patients' performance, avoid overloading and joint injuries, and ensure the safety and effectiveness of treatment. Through these specific practical operations, therapists can effectively adjust the treatment plan, helping patients gradually improve from their pre-assessment state and ultimately achieve the best rehabilitation effect after treatment. The evaluation of physical therapy and functional recovery effects for patients with sports injuries is shown in Table 1.

Table 1. Evaluation Table of Physical Therapy and Functional Recovery Effects for Patients with Sports Injuries.

Treatment method	Applicable stage	Therapeutic goal	Pre-treatment assessment	Post-treatment evaluation
Cold therapy	Acute stage	Relieve pain and inflammation	Pain score (0-10)	Pain score: 5
Electrotherapy	Acute to subacute stage	Promote blood circulation and relieve muscle tension	Muscle electrical activity (EMG	Muscle electrical activity: 25 μ V
Ultrasound therapy	Acute stage	Relieve swelling and promote healing	Swelling score (0-10)	Swelling score: 3
Strength training	From subacute to recovery period	Strengthen muscle strength and restore motor function	Maximum Power (1RM)	Maximum strength: 30kg
Joint range of motion recovery training	Recovery period	Enhance joint flexibility and range of motion	Joint range of motion (°)	Joint range of motion: 90°

5.2. Low-Impact Exercise Rehabilitation and Strength Training for Elderly Patients

With the advent of an aging society, the demand for exercise rehabilitation among the elderly is gradually increasing. Low-impact exercises and strength training can help elderly patients gradually recover and improve their physical function in a safe environment. Low-impact exercises, such as gait training, cycling, elliptical machine training and water walking, can effectively reduce the burden on joints, improve heart and lung function, enhance joint flexibility, and thus prevent sports injuries. Strength training helps to enhance muscle strength, increase bone density, reduce the risk of fractures, and improve exercise endurance. During gait training, the gait time was 1.8 seconds per step before

treatment and decreased to 1.5 seconds per step after treatment. The stride length increased from 30cm to 35cm. The gait time changed by 0.3 seconds before and after treatment, and the stride length increased by 5cm, indicating a visible improvement in gait coordination. During the cycling training, the patient's heart rate increased from 90 bpm to 120 bpm, with a change of 30 bpm, reflecting an enhancement in cardiopulmonary function. Before the treatment, the cycling time was 10 minutes. After the treatment, it was extended to 15 minutes, an increase of 5 minutes, indicating an improvement in endurance. In strength training, the patient's maximum strength (1RM) was 25kg before treatment and increased to 35kg after treatment, an increase of 10kg, indicating a significant improvement in strength. Before the treatment, the body fat percentage was 20%, but it dropped to 18% after the treatment, a reduction of 2%. This indicates an improvement in body composition, characterized by increased muscle mass and reduced fat percentage. Through real-time data monitoring and feedback, therapists can adjust the training program in real time based on the patient's heart rate, gait, strength and other data. Data feedback helps therapists ensure that each training step is in line with the patient's recovery process, enabling the patient to recover at the most suitable exercise intensity and ultimately improve from the pre-assessment condition to the target state after the assessment. The evaluation of the effects of low-impact exercise and strength training in elderly patients is shown in Table 2.

Table 2. Evaluation Form of Low-Impact Exercise and Strength Training Effects for Elderly Patients.

Training method	Applicable stage	Therapeutic goal	Pre-treatment assessment	Post-treatment evaluation
Gait training	Recovery period	Strengthen the lower limb strength and improve gait coordination	Gait cycle time (seconds): 1.8, stride length (cm): 30	Gait cycle time (seconds): 1.5, stride length (cm): 35
Cycling training	Recovery period	Improve cardiopulmonary function and enhance endurance	Heart rate (bpm): 90, cycling time (minutes): 10	Heart rate (bpm): 75, cycling time (minutes): 20
Elliptical machine training	Recovery period	Increase aerobic endurance and reduce the burden on joints	Maximum heart rate (bpm): 120, stride rate (steps per minute): 60	Maximum heart rate (bpm) : 110, cadaver (steps per minute): 70
Strength training	Recovery period	Strengthen muscle strength and improve bone density	Maximum strength (kg) : 25, bone mineral density (g/cm²) : 0.8	Maximum strength (kg) : 40, bone mineral density (g/cm²) : 1.0
Walking training in water	Recovery period	Reduce the burden on joints, increase muscle endurance and promote blood circulation	Joint range of motion (°) : 60, gait balance (seconds): 10	Joint range of motion (°) : 80 gait balance (seconds): 15

5.3. Personalized Exercise Rehabilitation Intervention and Real-Time Assessment of Rehabilitation Effects

Personalized intervention focuses on designing a comprehensive rehabilitation plan—including strength, flexibility, and aerobic training—tailored to the patient's age, gender, physical condition, and exercise capacity. Low-impact exercises, such as gait training, cycling and elliptical machine training, can provide effective aerobic exercise for the elderly and patients with chronic diseases, while reducing the burden on joints.

Strength training improves muscle strength and bone density, making it especially beneficial for elderly individuals and those with chronic conditions. During the treatment process, real-time data monitoring and feedback mechanisms played a crucial role. Through smart wearable devices, motion sensors, etc., therapists can obtain patients' movement data in real time, such as gait, muscle electrical activity, joint range of motion, etc., helping therapists optimize treatment plans based on the data and ensuring that the rehabilitation process is both scientific and safe. Before treatment, the gait time was 1.8 seconds per step and the stride length was 30cm. After treatment, the gait time decreased to 1.5 seconds per step and the stride length increased to 35cm. The difference in gait time before and after treatment was 0.3 seconds and the difference in stride length was 5cm, indicating that the patient's gait coordination improved. In terms of strength training, the patient's maximum strength was 30kg before the treatment and increased to 50kg after the treatment, an increase of 20kg, indicating a significant enhancement in muscle strength. In terms of body fat percentage, it was 22% before treatment and dropped to 20% after treatment, a reduction of 2%. This indicates that the patient's body composition has improved through strength training and aerobic exercise. The measurement of VO2max also showed an improvement in aerobic capacity. It was 20 ml/kg/min before treatment and increased to 30 ml/kg/min after treatment, changing to 10 ml/kg/min, indicating a significant improvement in aerobic endurance. Through real-time data monitoring and dynamic adjustment of training programs, therapists can ensure that treatment aligns with each patient's needs and supports progress toward their rehabilitation goals (Table 3).

Table 3. Application of Personalized Exercise Rehabilitation Intervention and Real-time Evaluation of Rehabilitation Effects.

Intervention type	Applicable patient group	Therapeutic goal	Evaluation indicators	Data before treatment	Post-treatment data
Gait training	Patients with sports injuries	Restore gait coordination and enhance lower limb strength	Gait cycle time (seconds), stride length (cm), gait stability (TUG test)	Stride length: 30cm gait cycle: 1.5 seconds TUG: 14 seconds	Stride length: 35cm, gait cycle: 1.2 seconds, TUG: 8 seconds
Muscle strength training	Patients with joint injuries or muscle atrophy	Strengthen muscle strength and improve joint stability	Maximum strength (1RM), Electrical muscle activity (EMG), endurance (minutes)	Maximum strength: 30kg, EMG: 50 μ V Endurance: 5 minutes	Maximum strength: 50kg, EMG: 80 μ V, Endurance: 12 minutes
Aerobic exercise	Patients with chronic diseases	Improve cardiopulmonary function and enhance endurance	Maximal oxygen uptake (VO2max), heart rate (bpm)	VO2max: 20ml/kg/min heart rate: 80bpm	VO2max: 30ml/kg/min, heart rate: 75bpm
Joint range of motion recovery training	The elderly and postoperative patients	Restore joint range of motion and relieve pain	Joint Angle (°), range of motion score (0-100)	Joint Angle: 40°, range of motion score: 60 points	Joint Angle: 75°, range of motion score: 90 points

Core strength training	Patients with sports injuries and poor posture	Improve core stability and enhance overall balance	Core muscle strength (kg), balance test (BESS)	Core strength: 10kg, BESS: 15 seconds	Core strength: 20kg, BESS: 8 seconds
Flexibility training	Patients with chronic pain	Improve muscle flexibility and increase joint flexibility	Muscle extensibility (cm), flexibility score (0-100)	Muscle extensibility: 20cm, flexibility score: 50 points	Muscle extensibility: 30cm, flexibility score: 85 points

6. Conclusion

With the continuous advancement of sports science and physical therapy techniques, the optimized path of sports rehabilitation has begun to develop in the direction of humanization and precision. By integrating modern technologies such as smart wearable devices, real-time data monitoring and dynamic feedback mechanisms, therapists can develop personalized rehabilitation plans for patients, helping them achieve more effective recovery, reduce treatment time, and lower the risk of re-injury. Low-impact exercises, strength training, and other methods have been widely applied in patient rehabilitation and have shown positive outcomes.

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