SIN-CHN SCIENTIFIC PRESS PTE.LTD.

Molecular & Cellular Biomechanics 2024, 21, 178.
https://doi.org/10.62617/mcb.v21.178

Article

Application of biomechanics in sports rehabilitation

Nannan Zhang

Jilin Animation Institute, Changchun 130012, Jilin, China; 15948757811@163.com

CITATION

Zhang N. Application of biomechanics in sports rehabilitation. Molecular & Cellular Biomechanics. 2024; 21: 178. https://doi.org/10.62617/mcb.v21.178

ARTICLE INFO

Received: 31 May 2024
Accepted: 23 July 2024
Available online: 6 August 2024

Abstract: The application of biomechanical methods and techniques in rehabilitation treatment has been explored to deepen understanding of the health recovery of injured athletes, thereby improving their efficacy and quality. There are various methods for using biomechanics, which can help people understand the patient's movement characteristics and mechanical changes, evaluate the patient's recovery progress, and optimize the plan. Therefore, this article mainly conducted research and analysis on the application of biomechanics in sports rehabilitation, and explained the specific role of biomechanics in it by comparing before and after sports rehabilitation in different situations. The results showed that after treatment with biomechanical methods, the patient's muscle strength increased by 9.4%–20.93% compared to the original, and the power value increased by 0.8–4.56 watts. The effect was good for achieving 71.28% muscle activity, and there was also a significant improvement in its sports mechanics indicators. After receiving biomechanical treatment, the quality of motor skills in patients was over 60%, which showed significant improvement compared to before treatment. Therefore, when conducting sports rehabilitation, biomechanical treatment plans should be used to achieve better therapeutic effects.

Keywords: sports rehabilitation; biomechanical technology; kinematic index; muscle strength value

1. Introduction

In daily life and work, many people lose their original physiological functions due to injuries. In order to regain their normal life and exercise abilities, rehabilitation training is necessary [1]. In the field of sports rehabilitation, biomechanics is a science used to study the principles of kinematics and dynamics [2,3]. It can provide people with data related to strength, velocity, acceleration, angular velocity, angular acceleration, etc. These data can assist rehabilitation physicians in understanding specific information about patient limb movements and developing personalized and efficient rehabilitation plans based on it [4]. In addition, biomechanical methods are used to evaluate and improve the patient's posture and movement status, reducing their instability and achieving good balance and coordination, as well as reducing injury and recurrence rates. Just as rehabilitation physicians can use real-time feedback and monitoring devices to monitor and adjust the patient's movement posture, strength output, and strengthen their special muscle groups according to the training plan. Moreover, during this process, sports rehabilitation can encounter many problems [5,6]. Exercise is crucial to people's health, but sometimes sports injuries come. Rehabilitation is a key step back to the playground, and biomechanics provides athletes with a new way to understand and address sports injuries. Simply put, biomechanics is the science of studying how the body moves and can help get a deeper understanding of the body changes and responses during exercise. However, these problems can be effectively prevented and resolved. Therefore, understanding the application of biomechanics in sports rehabilitation can better guide rehabilitation treatment, improve the quality and efficiency of recovery effects and treatment services, and ultimately achieve the goal of preventing and treating sports injuries.

Nowadays, there is a lot of research on sports rehabilitation, and many scholars have verified the rehabilitation status caused by a certain exercise technology and method, and have obtained many conclusions. On the basis of previous research on the human body’s motor ability and prevention of sports injuries, Ba used MRI (Magnetic Resolution Imaging) technology and combined deep learning method models to complete the task and development of a medical sports rehabilitation system, and conducted data analysis on it. The experiment showed that the robustness of this method was robust [7]. Ardern et al. believed that insufficient evaluation and reporting of medical and healthcare systems is an inevitable issue in sports and sports medicine, musculoskeletal rehabilitation, and sports science. He identified demonstration report examples in sports, sports medicine, musculoskeletal rehabilitation, and sports science system evaluations for each system review and meta-analysis priority report item, in collaboration with 19 content experts and 3 method experts. The results showed that transparent, accurate, and comprehensive system evaluation reports could be provided to researchers [8]. The purpose of Ebert was to investigate the current status of rehabilitation and RTS (Real time system) evaluation by plastic surgeons. A survey of 14 questions was released to members of the Joint Association and responses were provided. The results showed that 86% of all 85 members of the Joint Association contacted responded, indicating the benefits of this survey for preoperative and postoperative rehabilitation, as well as the potential for RTS assessment (including strength and functional measures) to reduce the rate of re injury [9]. DiSanti et al. evaluated perceptual function in patients with recent anterior cruciate ligament reconstruction (ACLR) and analyzed its positive and negative factors for motor rehabilitation. Therefore, he selected 10 high school age individuals as samples and conducted a face-to-face semi-structured interview with teenagers who had not yet been allowed to participate in sports after ACLR. The results of the study showed that comparing ACLR with others by parents and coaches can affect children’s feelings of recovery [10]. Greenberg et al. analyzed the current clinical application status due to the time and target standards used in the postoperative recovery process of ACLR. He conducted descriptive statistics on 1074 response samples and conducted research on the distribution, frequency, and dispersion of respondents’ responses. The results showed that more than 80% of these people reported using strength and functional measures during rehabilitation, and 56% used manual muscle testing as their only strength testing method [11]. However, most studies are relatively single, and its sports rehabilitation requires the use of some methods to conduct in-depth research.

The use of biomechanical methods for analyzing sports rehabilitation is an important research direction, and previous related studies have been widely applied and confirmed. Among them, Hamill et al. believed that as a branch of motor function, biomechanics can make significant progress. In the development of biomechanics, he utilized improved motion research techniques and linked them to several other fields of motor function, allowing researchers to answer more comprehensive questions and provide deeper answers to these questions. This also made an important contribution to enhancing the knowledge base of all fields [12]. Glazier and Mehdizadeh evaluated the effectiveness of traditional paradigms in applied sports biomechanics research and highlighted their existing problems. He found in empirical research that group based analysis often overlooks differences among athletes. Moreover, in personal analysis, performance parameters often exhibit small changes in amplitude, and a flat response is obtained in repeated performance experiments [13]. Phellan et al. believed that FEM (Finite element method) is the most ideal method to study human anatomy. Regarding the anatomical structure, data collection strategy, features corresponding to the selected ML (Machine Learning) algorithm, indicators used for validation, and time efficiency of the ML method used, it was found that the ML algorithm can be used to accelerate the speed of FEM based biomechanical simulation of anatomical structures and may achieve real-time response, which is helpful in shortening the time required for FEM based simulation and accelerating its application speed in clinical applications [14]. Ma et al. conducted research on the relationship between corneal biomechanics and structure, and discovered the correlation between corneal biomechanics and structure through preliminary work. Based on this, he conducted research on eye diseases and systemic diseases related to corneal biomechanics. The results indicated that changes in corneal biomechanical properties can cause corneal lesions, particularly corneal dilation. In addition, this change also affects the efficacy of corneal refractive surgery [15]. From the above research, it can be clearly understood that biomechanics has applications in many fields, and its role in it is also very effective.

Based on the research results of the above scholars and the current application, it can be seen that biomechanics plays a very important role in sports rehabilitation. Firstly, biomechanics can be used to evaluate the rehabilitation process, such as detecting improvements in muscle strength, joint stability, and motor ability during the rehabilitation process. Secondly, it can assist in developing the best recovery plan. Sports rehabilitation professionals can use this model to experiment with various rehabilitation training and techniques, and find the best methods to help patients regain motor function. In addition, it can also promote the recovery of motor function. For example, biomechanically customized orthotics [16] can be used to improve patient stability and balance, helping them regain the ability to walk and engage in other daily activities.

2. Overview of biomechanics and sports rehabilitation

2.1. Overview of biomechanics

Biomechanics is a discipline that studies the motion and mechanical properties of life systems, including humans and animals. It applies the fundamental principles of mechanics to biology, studying the mechanisms and effects of forces, rotation, and motion in organisms. Therefore, the scope of biomechanical research is very broad, from single cells, tissues, to all levels of the body. From the perspective of biomechanics, the mathematical model of the human body's forces and movements is studied. This model can be applied to the study of internal forces and movements in biological systems, as well as to the study of external movements or loads on the body. Biomechanics can provide theoretical basis for disease prevention and treatment by studying certain diseases, exercise, and daily activity patterns. At the same time, biomechanics also has a significant impact on the development of new medical devices such as orthopedics and prosthetics.

The application of biomechanics in sports rehabilitation is growing in popularity. It explores the mechanical characteristics and laws governing human movement by fusing the concepts of physics, physiology, and medicine. Modern biomechanical ideas that promote sports recovery include muscle activation patterns, 3D motion capture, and gait analysis.

To begin with, one of the key uses of biomechanics in sports rehabilitation is gait analysis. An individual's walking pattern can be examined in detail to determine whether it is normal or atypical in order to identify any potential dysfunction or risks for sports injuries. For patients with knee injuries, for instance, gait analysis can identify the aberrant force applied to the knee joint when walking. This information can then be used by the rehabilitation therapist to create a customized rehabilitation plan that includes strengthening muscles and adjusting gait. Second, 3D motion capture technology offers sports rehabilitation more thorough and precise data support. This is crucial for determining the severity of sports injuries, creating rehabilitation programs, and gauging how well rehabilitation is working. For instance, 3D motion capture technology can precisely record the trajectory and force of the knee joint during football players' kicking motions, which aids rehabilitation therapists in creating more precise rehabilitation regimens.

To give a specific example, a runner who was experiencing knee pain went to the doctor and, following a preliminary examination, the physician diagnosed the patient with patellofemoral joint syndrome. The patient's severe internal knee joint buckling when running was initially identified throughout the rehabilitation phase using gait analysis, which raised the pressure between the patella and the femur. Subsequently, 3D motion capture technology was employed to conduct an in-depth analysis of the patient's running motions and precisely record the knee joint's trajectory and angle changes. These data helped the rehabilitation therapist create a customized rehabilitation plan for the patient, which included strengthening the muscles surrounding the knee joint and changing the patient's running stance. In order to guarantee the progressive restoration of muscular function, the rehabilitation impact is also assessed during the procedure by keeping an eye on the pattern of muscle activation. In addition to advancing our knowledge of the mechanisms behind sports injuries and the rehabilitation process, these state-of-the-art biomechanical ideas offer more precise and practical instruments and techniques for sports rehabilitation practice.

2.2. Introduction to sports rehabilitation

Sports rehabilitation is an activity that primarily uses exercise as a means to restore the function and health of the human body. It can help people recover body function and improve physical fitness, including exercise, strength, flexibility, and coordination, after surgery, illness, or trauma. The types and levels of sports rehabilitation vary with individual differences, including rehabilitation exercise, rehabilitation training, or massage. In cases of muscle injury, ligament injury, knee joint injury, etc., these rehabilitation techniques can be used to restore athletic ability or contribute to daily life. A large number of studies have shown that sports rehabilitation can not only effectively restore human body functions, but also enhance the long-term health of the human body. Therefore, sports rehabilitation, as an important component of rehabilitation therapy, also provides a feasible rehabilitation method for patients who want to improve their physical fitness and reduce disease risk.

An essential component of sports recovery is biomechanics. It entails researching the mechanical characteristics of the human body during exercise and applying this understanding to enhance the healing process. As science and technology continue to advance, wearable sensors, virtual reality (VR), and augmented reality (AR) are just a few examples of cutting-edge technologies that have recently made biomechanical assessment and rehabilitation easier and more effective.

In order to provide precise data support for biological analysis, wearable sensors can monitor and record human body movement data in real time, including joint angle, muscle activity, movement speed, etc. Rehabilitation therapists can more precisely diagnose patients' movement abnormalities and create a customized rehabilitation plan for them with the use of data gathered by wearable sensors. Wearable sensors, for instance, can measure a patient's walking gait parameters, such as step length, stride speed, joint angle, etc., in a gait analysis. The rehabilitation therapist can determine the patient's aberrant gait and create a customized rehabilitation strategy by comparing the data on normal gait. In addition, the sensor can track the patient's advancement through the rehabilitation process in real time and give the rehabilitation therapist feedback so that the treatment plan can be modified on schedule.

The application of virtual reality (VR) technology in biomechanical assessment and rehabilitation is also common. With the use of virtual reality technology, sports scenarios may be created, real-world sports situations can be simulated, and patients can receive rehabilitation training in a virtual setting. This approach can lower the hazards associated with rehabilitation while also increasing the patient's excitement for the process. Virtual reality technology may imitate several sports settings for rehabilitation therapy, including strength and balance exercises. To enhance their motor abilities and the results of their therapy, patients can do the same exercises repeatedly in a virtual setting. Simultaneously, VR technology can offer patients real-time feedback and advice to help them rectify incorrect actions and improve their training regimens.

2.3. Evaluation of sports rehabilitation

Sports rehabilitation is a process of evaluating motor function, helping health care professionals develop specific rehabilitation plans, and tracking rehabilitation progress. The evaluation is generally divided into the following parts:

(1) Sports performance evaluation [17]: Various indicators of sports

performance, such as oxygen consumption, cardiopulmonary function, muscle strength, and flexibility, are evaluated. Muscle strength can be evaluated by measuring maximum oxygen intake, or functional testing can be conducted.

(2) Assessment of pain and discomfort: It can be evaluated through two methods: a “pain scale” or “physical discomfort”, which helps physicians develop treatment methods to alleviate pain and discomfort and improve athlete performance.

(3) Neurological function assessment: It mainly evaluates the function, balance, and coordination of the nervous system. The evaluation can be conducted using two methods: neural system method and balance test.

(4) Activity evaluation: The evaluated daily life behaviors include walking, going up and down stairs, sitting up, lying down, etc. By evaluating the degree of exercise and function, the purpose of rehabilitation can be determined, and a rehabilitation plan can be formulated accordingly.

(5) Psychological assessment: It can be comprehensively evaluated from aspects such as mental health and body image assessment, as well as the level of participation and motivation in treatment plans.

(6) Health risk assessment: By assessing risk factors such as cardiovascular disease, metabolic disease, depression, and anxiety, the risk factors and treatment methods in rehabilitation plans are evaluated.

Sports rehabilitation makes extensive and detailed use of biomechanics. It entails researching the mechanical characteristics of the human body during exercise and applying this understanding to enhance the healing process. Sports injury causes, mechanisms, and changes in the rehabilitation process can all be better understood through biomechanical analysis, which can also serve as a foundation for the development of more rigorous rehabilitation regimens. Longitudinal data collection and analysis is crucial to a thorough knowledge of changes in biomechanical parameters during the rehabilitation process. The term “longitudinal data” describes the routinely recorded biomechanical characteristics of patients over time in order to track any patterns in their recovery. These variables could be things like movement speed, muscle strength, and joint range of motion. A more thorough understanding of the dynamic changes in the rehabilitation process can be achieved through the analysis of longitudinal data. Early on in the recovery process, there may be a noticeable downward trend in several biomechanical indicators. This indicates that the patient’s motor capacity has been negatively impacted by the injury. These metrics gradually exhibit an upward trend as rehabilitation training advances, indicating that the patient’s motor capacity is gradually improving. Furthermore, longitudinal data can be used to pinpoint important milestones and phases in the recovery process. Biomechanical parameter changes can occur suddenly at certain times, indicating that the patient may need to modify their rehabilitation program or add additional exercise.

2.4. Biomechanical treatment strategies

Biomechanical treatment strategy is a new method of rehabilitation training for patients using the basic principles of biomechanics. Understanding and applying biomechanical principles can optimize treatment outcomes and reduce unnecessary harm. Here are some common biomechanical strategies:

(1) Sports orthopedics: The basic principles of biomechanics are utilized to design personalized sports orthopedic plans from aspects such as changing posture, adjusting joint position and function, and improving motor skills, in order to correct posture and improve motor efficiency.

(2) Dynamic analysis [18,19]: The imbalance of human function and movement mode is analyzed by biological kinematics and dynamics, and evaluated, so as to determine the rehabilitation plan and optimize the rehabilitation effect.

(3) Robot assisted therapy [20,21]: In the rehabilitation process of robot assisted therapy, biomechanical methods are applied to provide external support for patients, strengthen muscle strength, and help patients recover motor function, thus achieving the goal of rehabilitation.

(4) Orthopedic treatment: Based on biomechanical principles and techniques, as well as the patient's body shape and condition, a set of orthoses that are suitable for the patient's body shape and condition and can correct the patient's posture is designed and manufactured to reduce its impact on the patient.

Biomechanical treatment strategy is a widely used therapy that can be used to treat various diseases such as bones, muscles, nerves, and sports injuries [22]. The use of biomechanical technology for rehabilitation treatment has the advantages of precision, efficiency, and short duration, which can ensure rapid and efficient recovery of patients and improve their quality of life [23,24].

In addition to helping athletes regain their physical abilities, the application of biomechanics in sports rehabilitation has close ties to other disciplines, particularly when it comes to the psychological effects on players' performance and morale. In order to apply biomechanics to sports rehabilitation, athletes' psychological states must also be considered and modified. After an injury, athletes frequently experience negative emotions including anxiety and depression. These feelings may have a long-term effect on their athletic career and performance in addition to the healing procedure. Thus, psychological counseling and psychological counseling are essential during the rehabilitation process to assist athletes in changing their mindset and actively overcoming the obstacles of recovery in addition to attending to their physical condition. Athletes' unnatural movement patterns and possible hazards can be identified through biomechanical evaluation, and their sports performance can subsequently be optimized through focused training and modification. In addition to helping athletes heal physically, this all-encompassing rehabilitation approach raises their competitive level and athletic prowess while also boosting their self-esteem and morale.

3. Methods and applications of biomechanics in sports rehabilitation

3.1. Methods of biomechanics in sports rehabilitation

Sports rehabilitation has demonstrated a significant potential and benefit for the application of biomechanics, particularly in computer models. In addition to simulating and predicting the outcomes of injuries, computational models like musculoskeletal modeling and finite element analysis (FEA) also strongly promote the creation of individualized rehabilitation plans. A mathematical approximation technique called finite element analysis (FEA) is used to mimic the behavior of actual physical systems [25,26]. FEA is frequently used in the field of biomechanics to mimic the mechanical properties of human bones, muscles, and other tissues. FEA can estimate the stress and strain that can be experienced in different body parts under particular sports or stress conditions by developing intricate mathematical models, which can then be used to estimate the risk of injury. This offers a crucial theoretical foundation for sports rehabilitation, assisting medical professionals and rehabilitation therapists in comprehending the mechanism and course of injuries in order to create more precise rehabilitation plans.

Biomechanics is a precision technology that can be used to analyze and study the performance of various mechanical systems, especially for humans and animals, with strong adaptability [27–29]. The research methods and calculation formulas of biomechanics have been widely applied in the field of sports rehabilitation, such as the following formulas:

Newton's Second Law:

$$F = ma \tag{1}$$

In Equation (1), F is the force, m is the mass of the object, and a is the acceleration received by the object.

The law of muscle reaction force:

$$S = -S' \tag{2}$$

In Equation (2), S is the active force and S' is the reaction force. This formula is used to illustrate that during exercise, the active and reactive forces that muscles bear are equal but opposite in direction.

Shoulder abduction moment during the end of standard action normal:

$$M = N \times d \tag{3}$$

In Equation (3), M represents the shoulder abduction moment, N represents the horizontal force on the center of mass, and d represents the vertical distance from the center of mass to the shoulder joint.

Centroid trajectory: The commonly used formula is the Heisenberg principle.

$$xh = \Delta p \Delta x \geq h/4\pi \tag{4}$$

In Equation (4), xh represents the centroid uncertainty constraint, ΔP represents the uncertainty constraint of momentum, and ΔX represents the uncertainty constraint of position.

Deceleration: Deceleration is the ratio of the rate of change to time.

$$c = \Delta v/\Delta t \tag{5}$$

In Equation (5), c represents deceleration, v represents velocity, and t represents time.

Muscle torque: This is an indicator used to measure muscle strength and control parameters of human motion.

$$Z = Px(d1 + d2) \tag{6}$$

In Equation (6), Z is the knee muscle torque, and P is the force generated by the muscle. $d1$ is the distance from the junction point of the quadriceps femoris muscle muscle to the joint center, and $d2$ is the distance from the junction point of the semitendinosus muscle to the joint center.

According to the method mentioned above, the mechanical properties of joints vary under different motion states. Therefore, when conducting rehabilitation training, these formulas can provide doctors and other professionals with a good understanding of the biomechanical characteristics of the human body, the forces generated, and the interaction between muscles and bones, in order to develop better rehabilitation training and treatment plans for rehabilitation patients.

The utilization of biomechanics in sports recovery is amazing. It can aid in a better understanding of how the human body functions during athletic competition, as well as the origins of sports injuries and the healing process. A customized rehabilitation plan can be created by precisely measuring and analyzing a person’s movement patterns, muscle activity, joint and bone stress, and biomechanical assessment. There are many extensively used specialized assessment techniques and processes in biomechanical evaluation. Among these, electromyography (EMG) and motion capture systems are two crucial instruments.

The motion capture system, which records the motion of moving objects through several video capture devices organized in space, is primarily based on the principles of computer graphics. This approach is typically used in sports rehabilitation to examine a person’s posture, gait, and the trajectory of particular motions. The individual’s exercise efficiency, stability, and symmetry can be assessed by precise measurement and recording in order to identify any potential issues with their exercise routine. It is necessary to develop an appropriate model before deploying a motion capture device. Typically, this entails establishing the capture’s joint point as well as its frequency, accuracy, and other settings.

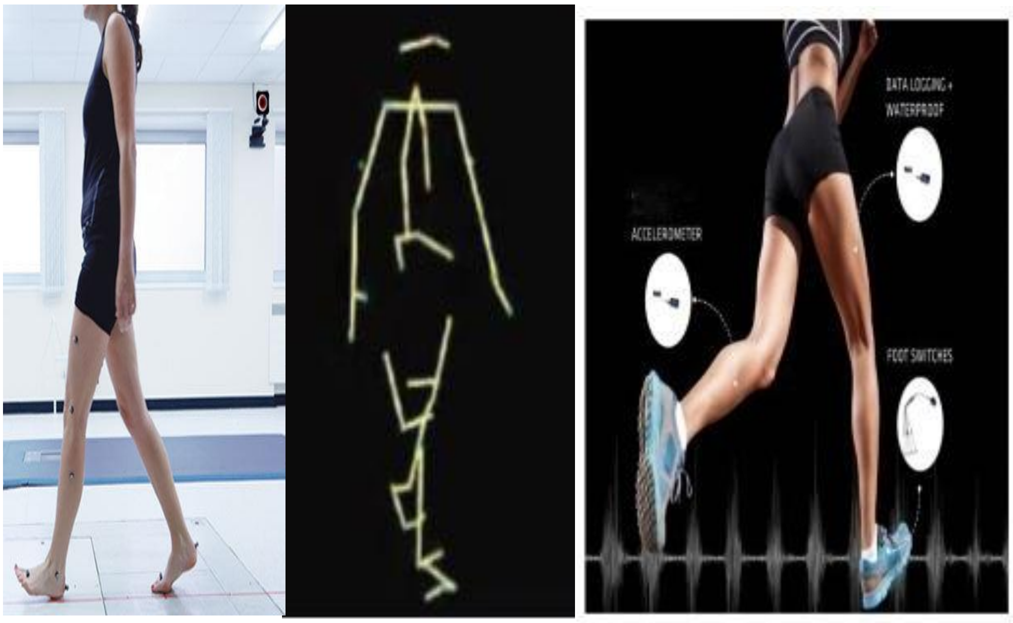
Conversely, muscular electrical activity can be recorded and analyzed using electromyography (EMG). You can determine the degree, pattern, and synergy of muscle activation during exercise by using electromyography (EMG). This is crucial for assessing muscle function, identifying muscle damage, and creating recovery strategies. Considerations including electrode placement, sampling frequency, and filtering settings must be made while determining the EMG parameters. To ensure that the electrical activity of the target muscle can be reliably recorded, the electrode placement normally has to be decided depending on the examined muscle group. The evaluation’s goal and accuracy standards must be taken into consideration while selecting the sampling frequency. While higher sample frequencies can yield more detailed data, they will also make data processing more complex. The purpose of the filtering option is to increase the data’s signal-to-noise ratio by eliminating interfering signals and background noise.

3.2. Application effect of biomechanics in sports rehabilitation

Biomechanics is a science that applies the principles of mechanics to study and test the mechanical properties of living system motion. In sports rehabilitation, biomechanics is used to analyze the mechanical characteristics of movement, which has certain reference value for doctors and rehabilitation practitioners to understand and formulate rehabilitation training plans. The application of biomechanics in sports rehabilitation includes the following aspects:

(1) Movement analysis: Biomechanics is used to analyze the characteristics of kinematics, mainly including strength, speed, angle, acceleration, muscle torque, which has a certain guiding significance for the development of rehabilitation plans and the evaluation of sports training effects. Movement analysis can be carried out using the measurement techniques of motion capture [30] and electromyography [31].

In **Figure 1**, the method used in biomechanical motion analysis is described [32–34]. By using motion capture in **Figure 1a**, computational processing can be performed, providing users with technical services such as fast data collection, batch data processing, and simple report output. **Figure 1b** can be analyzed using signal receivers attached to the body surface to determine when different muscles contract during exercise, the intensity of contraction, and so on, which helps to exercise muscles in a targeted manner.



(a) Motion capture. **(b)** Electromyography.

Figure 1. Biomechanical motion analysis.

(2) Identifying key muscles: Biomechanical methods can be used to determine the specific angles of the patient’s key muscles (main motor muscles, auxiliary motor muscles, antagonistic muscles) during specific joint movements, which can help the patient determine the required muscle strength and arm strength [35,36].

Figure 2 shows the main motor muscles, antagonistic muscles, and force points of the arm, which allows for a better understanding of the strength and state of the joints in the arm during movement, thus developing targeted training plans to prevent secondary injuries.

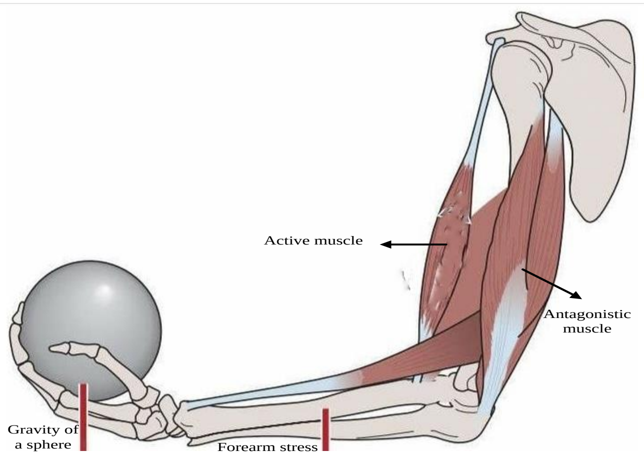


Figure 2. Arm muscle recognition.

(3) Technical evaluation and improvement: Biomechanics is utilized to evaluate motor skills, identify problems, and optimize movements. Physicians or rehabilitation therapists can use these programs to provide better rehabilitation plans and training for athletes and rehabilitation patients.

The program in **Figure 3** is used for testing and generating suitable solutions, and biomechanical techniques and methods are used to derive the results of motor movements. Corresponding measures are taken to assist rehabilitation patients in achieving these tasks and evaluating rehabilitation outcomes.

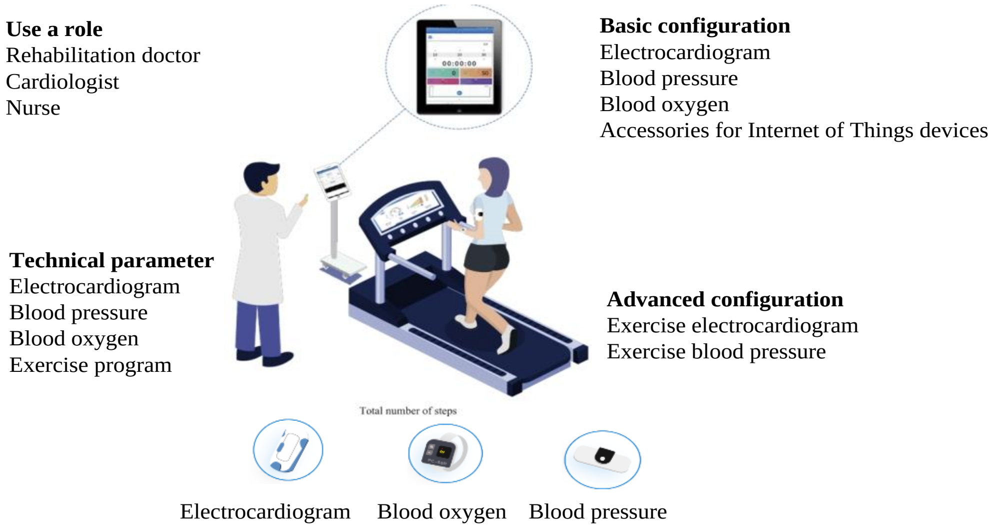


Figure 3. Sports rehabilitation program.

(4) Sports diagnosis and prediction: Biomechanical techniques are used to diagnose motor dysfunction or acute sports injuries, analyze the mechanical characteristics of sports, and develop personalized prediction and rehabilitation plans, enabling patients to recover as soon as possible.

According to **Figure 4**, biomechanics can predict the 10 most vulnerable locations, thereby helping to determine the potential harm that patients may suffer. Based on the predicted results, rehabilitation therapists can provide targeted training on important muscles to help patients adapt to exercise as soon as possible, accelerate the rehabilitation process, and better achieve effective rehabilitation goals for patients.

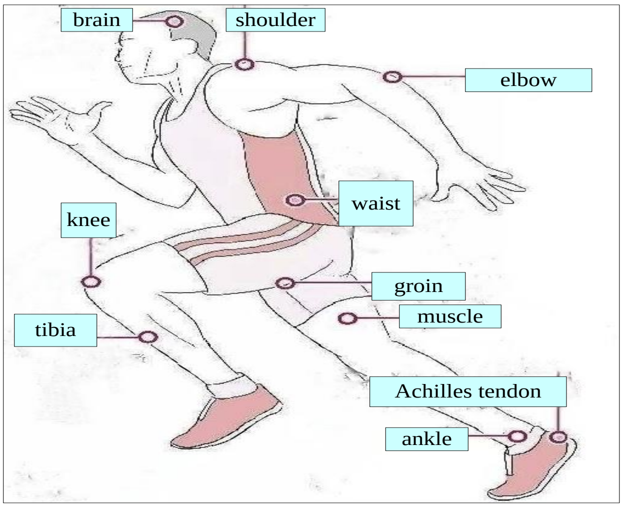


Figure 4. Diagnostic prediction of the ten most vulnerable sites.

Therefore, biomechanics is an important scientific tool in sports rehabilitation, which can effectively analyze and study the mechanical characteristics of human motion, and help develop better training plans to improve the rehabilitation effect of patients.

A key component of sports recovery is biomechanics. It offers a scientific foundation for the creation of individualized rehabilitation strategies in addition to aiding in the proper evaluation of a person’s athletic ability and injury status. Anterior cruciate ligament (ACL) injuries of the knee joint are the specific sport or injury type for which this article will build and describe a biomechanical information training program. It will also demonstrate how this program can be incorporated into the recovery process.

Prior to the injury, ascertain the patient’s exercise routine and level of intensity, as well as the particular circumstances surrounding the injury. In both static and dynamic settings, the patient’s knee joint stability, muscular strength, and joint range of motion are assessed using wearable sensors and three-dimensional motion capture technologies. Additionally, evaluate the patient’s functional recovery by administering particular knee joint function tests such side leaps, one-leg jumps, etc. By using proprioceptive training and balancing exercises, you can increase the stability of your knee joint. To strengthen the muscles surrounding your knee joint, focus on intense training for your front and rear thigh muscles. Additionally, gradually restore the knee joint’s normal range of motion using gentle stretches and joint activity activities.

To guarantee the science and efficacy of rehabilitation programs, physicians who specialize in sports medicine, biomechanics, and rehabilitation therapy collaborate closely. Give patients a thorough explanation of biomechanical principles and their significance for rehabilitation; this will motivate patients to take an active role in their care and enhance the effectiveness of their rehabilitation. Give patients an enjoyable and effective rehabilitation training experience by utilizing virtual reality (VR) and augmented reality (AR) technologies. For instance, patients can exercise their muscles and knee joint stability in a virtual setting by using VR technology to replicate real-world sporting events. In order to aid patients in understanding and mastering the proper training techniques, augmented reality (AR) technology is also utilized to display the patient's motions and postures in real time. The biomechanical information training program for ACL injuries can be successfully included into the rehabilitation process by taking the aforementioned steps, giving patients access to effective, individualized, and scientific rehabilitation services. In addition, this type of training program fosters the long-term growth of the sports rehabilitation industry and raises the professional standards and caliber of care provided by rehabilitation therapists.

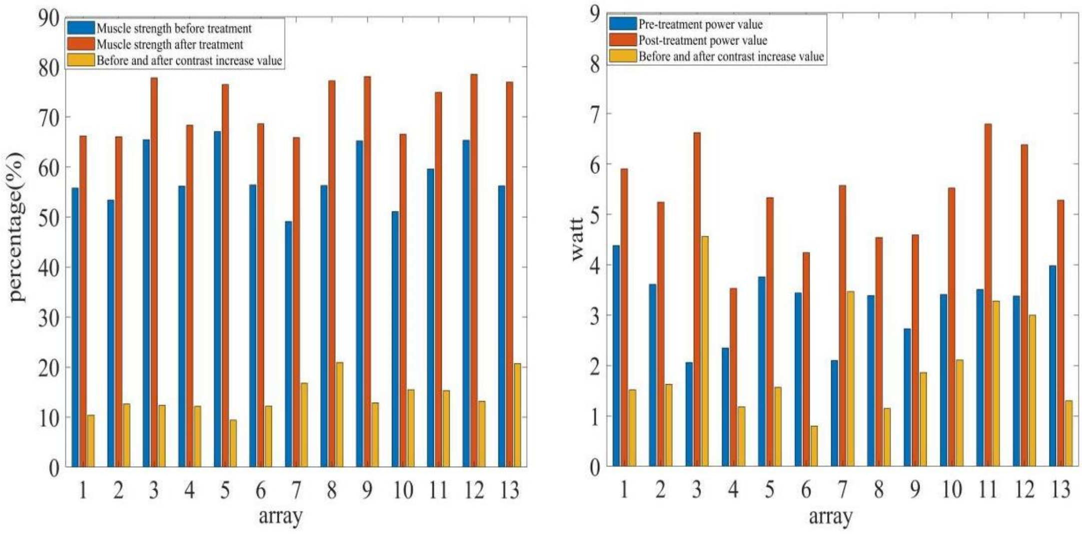
4. Application results of biomechanics in sports rehabilitation

In this article, biomechanical indicators before and after different exercise treatments are compared to better understand the progress of rehabilitation and the improvement of motor skills. For rehabilitation patients, quantitative indicators are often the basis for understanding and evaluating the effectiveness of rehabilitation. Biomechanical comparison is a quantitative analysis method that applies biomechanics to sports rehabilitation. Through the comparison before and after, the biomechanical changes that occur during the rehabilitation process and the remote effects of patients can be understood, which can play a positive role in improving and optimizing rehabilitation plans.

4.1. Strength indicators

Strength indicators are a key factor in the process of human movement. This indicator reflects the patient's ability to withstand a certain action, usually expressed as maximum muscle strength or power. It reflects the changes in muscle strength before and after treatment, and is an important biomechanical indicator for evaluating the recovery of motor function. By comparing the muscle strength and power values before and after treatment, it is helpful for rehabilitation physicians and patients to understand the treatment effect. **Figure 5** shows the comparison results of strength indicators before and after treatment.

Figure 5 shows the comparison of strength index data before and after the entire treatment. This article compared muscle strength and power values separately. From the 13 groups of data selected in **Figure 5a**, the muscle strength values before and after treatment, as well as the comparative improvement values before and after treatment, showed that the maximum muscle strength value before treatment was 67.06%, and the minimum was 49.1%. The maximum muscle strength value after treatment was 78.51%, and the minimum was 65.87%. Compared with before treatment, the patient's muscle strength increased by 9.4%–20.93% after treatment. From **Figure 5b**, it can be seen that the maximum power value before treatment was 4.38 watts and the minimum was 2.06 watts. The maximum value after treatment was 6.79 watts, and the minimum power was 3.53 watts. Compared to before and after treatment, the power value after treatment can be increased by 0.8–4.56 watts. It can be seen that after applying biomechanical therapy, strength indicators have a good effect on improving the patient's muscle strength and power level, and this effect is also reflected in different patients.



(a) Muscle strength. **(b)** Power values.

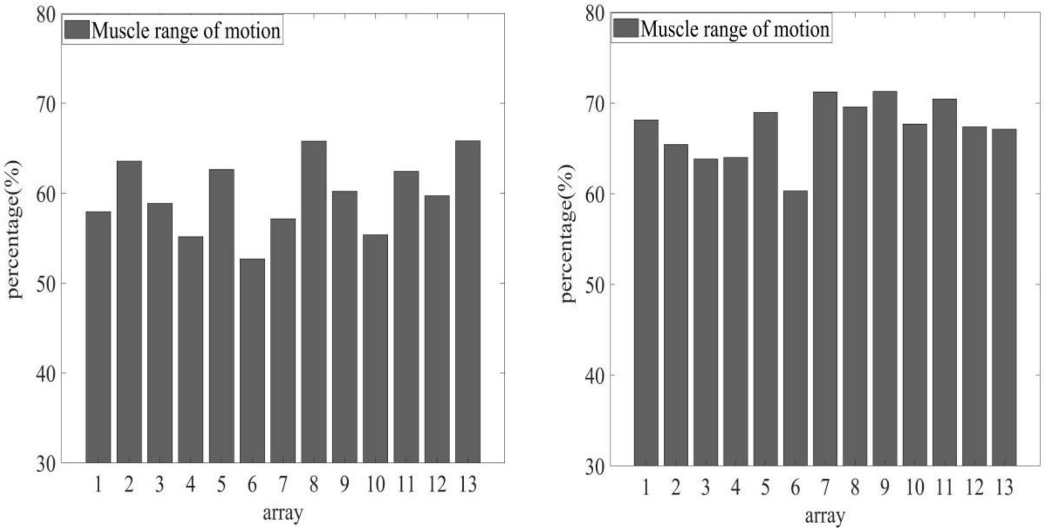
Figure 5. Comparison of strength indicators before and after treatment.

Since the data did not satisfy the assumption of normal distribution, Wilcoxon signed-rank test was used to assess the effect of training on muscle strength. The results showed a significant median increase in muscle strength after training. The *p*-value is 0.001, less than 0.05, and the muscle strength of the experimental participants is significant after the experiment.

4.2. Muscle activity

Muscle activity refers to the number of contraction or extension movements caused by muscles, also known as electromyographic activity. When implementing biomechanical therapy, electromyographic activity measurement can be used to determine the treatment effect and the patient's muscle function. An important purpose of sports rehabilitation therapy is to utilize muscle activity to improve the mobility of a particular joint. Therefore, comparing muscle activity before and after treatment can better understand the biomechanical effects of rehabilitation. **Figure 6** shows the comparison results of muscle activity before and after treatment.

In **Figure 6**, the *x* axis represents 13 data sets, the *y* axis represents 100% (%), the left panel is a before treatment, the right panel is b after treatment. From the comparison of data shown in **Figure 6**, it can be seen that the application of biomechanical therapy can improve the muscle activity of patients. Among them, as shown in **Figure 6a**, the highest and lowest muscle activity before treatment was 65.82% and 52.69%, respectively. In **Figure 6b**, the highest and lowest muscle activity after treatment was 71.28% and 60.3%, respectively. Therefore, it can be seen that this biomechanical treatment plan can effectively improve muscle activity and is likely to be a very effective treatment method.

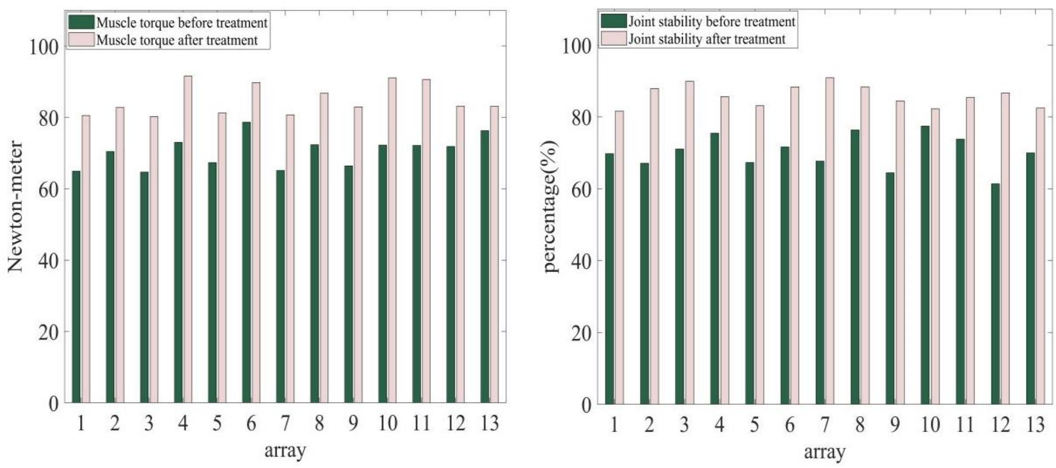


(a) Before treatment. **(b)** After treatment.

Figure 6. Comparison of muscle activity before and after treatment.

4.3. Sports mechanics indicators

The index of sports mechanics refers to the indexes of various force states, force output and kinematics parameters produced by the human body in the process of movement. This index reflects the changes of torque and joint stability produced by muscles, so as to evaluate the improvement of patients' sports skills. Therefore, comparing the biomechanical indicators of exercise before and after treatment can help rehabilitation therapists understand the performance of exercise, thereby reflecting the client's adaptability and control. **Figure 7** shows the comparison results of biomechanical indicators before and after treatment.



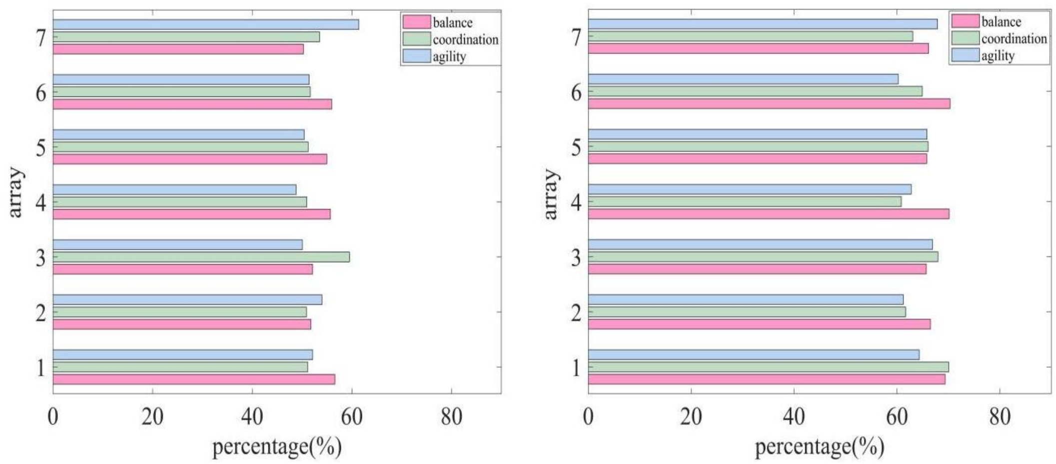
(a) Muscle moments. **(b)** Joint stability.

Figure 7. Comparison of motor mechanics indexes before and after treatment.

In **Figure 7**, the *x*-axis of figures a and b represent 13 sets of data. The picture on the left shows the muscle torque of **Figure 7a**, and the picture on the right shows the joint stability of **Figure 7b**. The *y*-axis in figure a represents Newton meters, a unit, and the y-axis in **Figure 7b** represents 100% (%). From the data analysis in **Figure 7**, it can be seen that the application of biomechanical therapy has improved muscle torque and joint stability. From **Figure 7a**, it can be seen that in the comparison of muscle torque before and after treatment, the highest and lowest values were 78.67 Newton meters and 64.67 Newton meters before treatment, while the highest and lowest values were 91.59 Newton meters and 80.19 Newton meters after treatment. The muscle torque after treatment was significantly higher than before treatment, indicating that the biomechanical treatment plan has a good effect on improving muscle strength. From the comparison of joint stability before and after treatment shown in **Figure 7b**, it can be seen that before treatment, the highest reached 77.44% and the lowest was 61.39%, while after treatment, the highest reached 90.9% and the lowest was 81.62%. The results showed that there was a significant improvement in stability compared to before treatment. Therefore, in biomechanics based indicators of exercise mechanics, the greater the torque, the better the muscle's strength and function recovery. A stable joint can reduce the risk of injury and improve the body's ability to control movement.

4.4. Degree of change in the quality of motor skills

The degree of change in the quality of motor skills refers to the changes in the technical performance and quality of various body movements before and after treatment. From a biomechanical perspective, changes in athletes' balance, coordination, agility, and other qualities often affect their athletic abilities. Therefore, comparing the quality changes of motor skills before and after treatment can be used to evaluate the treatment effect and provide targeted guidance and improvement training plans for rehabilitation personnel. **Figure 8** shows the comparison results of the quality changes in motor skills before and after treatment.



(a) Before treatment. **(b)** After treatment.

Figure 8. Comparison of quality changes in motor skills before and after treatment.

From the comparison of data shown in **Figure 8**, it can be seen that the overall degree of change in motor skill quality was higher after treatment than before. From **Figure 8a**, it can be seen that the overall scores of balance, coordination, and agility of motor skills before treatment were below 65%, indicating that the quality of motor skills of this group of athletes before treatment is relatively low. In **Figure 8b**, the scores of all indicators after treatment were above 60%, indicating a significant improvement in the quality of motor skills of the treated subjects. Overall, the quality changes after treatment are generally higher than before, indicating that biomechanical treatment regimens can effectively improve athletes' balance, coordination, agility, and other sports abilities.

5. Discussion

Case studies or what-if scenarios can help provide a more detailed explanation of how biomechanics is applied in sports rehabilitation. This article will examine the changes in particular biomechanical data before and after rehabilitation to reflect the usefulness and efficacy of biomechanical interventions. It will do this by using a hypothetical scenario to demonstrate how biomechanical treatment strategies can be applied to the real sports rehabilitation environment.

What-if scenario: Mr. A, a thirty-year-old basketball player, had surgery to repair a right knee anterior cruciate ligament damage. Following the procedure, he experienced issues with muscle atrophy, diminished stability in his knee joint, and limited motor function. He made the decision to employ biomechanical treatment techniques for rehabilitation in an effort to aid him in regaining his athletic skills. Using biomechanical assessment instruments, Mr. A is first given a thorough evaluation prior to starting the rehabilitation process. His gait patterns when walking and running were captured using the 3D motion capture equipment, and it was discovered that his knee joint exhibited aberrant valgus movement when bearing weight, indicating that the knee joint's stability is inadequate. On the basis of the evaluation results mentioned above, Mr. A. was given a customized rehabilitation plan. To improve the strength and stability of the muscles surrounding the knee joint, the strategy calls for focused strength training. Biomechanical evaluation instruments are utilized on a regular basis to track Mr. A's progress in his recovery. His knee joint stability gradually improved and his gait gradually recovered to normal with routine gait analysis and EMG testing. Following several months of instruction in rehabilitation, Mr. A underwent evaluation. His knee joint's stability has much improved, and his gait has essentially returned to normal compared to before the therapy. His knee joint's valgus movement was considerably lessened when he was bearing weight, according to the 3D motion capture system.

The usefulness and practical implementation of biomechanical treatment approaches in sports rehabilitation are demonstrated by this fictitious situation.It is feasible to precisely comprehend the injury state and dysfunction of athletes and create a customized rehabilitation plan with the help of a thorough biomechanical evaluation. The successful execution of the rehabilitation plan can be ensured during the process by using biomechanical assessment tools to regularly monitor and modify the therapy's progress.

We do gain many useful insights and techniques from the application of biomechanics in sports rehabilitation. But there are possible drawbacks to any scientific methodology or technological advancement, and biomechanics in sports rehabilitation is no different. First of all, biomechanical research is frequently based on particular sample groups, such as young athletes or participants in particular sports, with respect to the generalizability of research results to different populations.

Particularly for the elderly, those with long-term health conditions, and office workers who have a sedentary lifestyle, the findings of these research might not be entirely transferable to other populations. As a result, the relevance of biomechanical research findings to various populations must be carefully evaluated and modified in accordance with unique circumstances. Secondly, the external effectiveness of laboratory-based measures might be limited. Most of the time, the laboratory setting can regulate a number of variables to improve the accuracy of biological factor studies. The real-world sports setting, however, can differ greatly from this control condition. For instance, gait analysis performed in a lab might not accurately replicate a person's everyday walking circumstances. Thus, there can be certain hazards involved in directly using laboratory-based biomechanical research findings in the rehabilitation process.

While there are numerous benefits to using biomechanics in sports recovery, there are also some possible drawbacks. In order to create individualized rehabilitation plans, biomechanical evaluation tools and protocols for sports rehabilitation must take into account all relevant factors, including external effectiveness, potential technical difficulties, and applicability. Clinical observation and evaluation, individual medical histories, and other data are also combined.

6. Conclusions

Sports injury is an unavoidable issue for athletes during training and competition. In order to solve this problem, this article mainly compared the biomechanics before and after different sports rehabilitation to illustrate whether there is a method that can improve rehabilitation efficiency under the same conditions when problems arise. Through comparative analysis of experimental data, it was found that the application of biomechanical therapy can effectively improve the muscle strength and power values of patients, and the muscle strength and power values of patients after treatment have significantly improved. It has a good effect on improving muscle activity, helping to improve the muscle function of patients, effectively enhancing their balance, coordination, agility, and other sports technical indicators, thereby improving the quality of their sports skills. Therefore, the use of biomechanical treatment regimens is highly promising, especially for patients who require improvement in muscle strength, muscle activity, and motor skill quality. In the process of implementing biomechanical therapy, it is necessary to develop different therapies for different patients in order to achieve better results.

One area that has a lot of promise for future study is the integration of wearable sensors and artificial intelligence into biomechanical assessments to create more individualized rehabilitation strategies. First of all, a more practical and precise way to gather data for biomechanical assessment has been made possible by the advancement of wearable sensor technologies. These sensors can continuously and real-time collect data to enable the creation of rehabilitation plans by tracking an athlete's posture, muscle activity, and other physical attributes. Subsequent studies may investigate the integration of wearable sensors with biomechanical evaluation techniques to attain a more precise and all-encompassing evaluation of athletes' physical conditions. Second, a lot of biomechanical data may be mined and analyzed using machine learning, deep learning, and other technologies. This allows for the discovery of laws and patterns buried in the data, which is very supportive of the creation of individualized rehabilitation strategies. Future studies can investigate the application of artificial intelligence technology to automatically process and evaluate the data gathered by wearable sensors in order to extract information that can be helpful in the planning of rehabilitation.

Ethical approval: Not applicable.

Conflict of interest: The author declares no conflict of interest.

References

1. Farì G, Santagati D, Macchiarola D, et al. Musculoskeletal pain related to surfing practice: Which role for sports rehabilitation strategies? A cross-sectional study. Journal of Back and Musculoskeletal Rehabilitation. 2022; 35(4): 911-917. doi: 10.3233/bmr-210191
2. De Fazio R, Mastronardi VM, De Vittorio M, et al. Wearable Sensors and Smart Devices to Monitor Rehabilitation Parameters and Sports Performance: An Overview. Sensors. 2023; 23(4): 1856. doi: 10.3390/s23041856
3. Yung KK, Ardern CL, Serpiello FR, et al. Characteristics of Complex Systems in Sports Injury Rehabilitation: Examples and Implications for Practice. Sports Medicine—Open. 2022; 8(1). doi: 10.1186/s40798-021-00405-8
4. Dixon G, McGeary D, Silver JK, et al. Trends in gender, race, and ethnic diversity among prospective physical medicine and rehabilitation physicians. PM&R. 2023; 15(11): 1445-1456. doi: 10.1002/pmrj.12970
5. Wong J, Kudla A, Pham T, et al. Lessons Learned by Rehabilitation Counselors and Physicians in Services to COVID-19 Long-Haulers: A Qualitative Study. Rehabilitation Counseling Bulletin. 2021; 66(1): 25-35. doi: 10.1177/00343552211060014
6. Loveland PM, Reijnierse EM, Island L, et al. Geriatric home-based rehabilitation in Australia: Preliminary data from an inpatient bed-substitution model. Journal of the American Geriatrics Society. 2022; 70(6): 1816-1827. doi: 10.1111/jgs.17685
7. Ba H. Medical Sports Rehabilitation Deep Learning System of Sports Injury Based on MRI Image Analysis. Journal of Medical Imaging and Health Informatics. 2020; 10(5): 1091-1097. doi: 10.1166/jmihi.2020.2892
8. Ardern CL, Büttner F, Andrade R, et al. Implementing the 27 PRISMA 2020 Statement items for systematic reviews in the sport and exercise medicine, musculoskeletal rehabilitation and sports science fields: the PERSiST (implementing Prisma in Exercise, Rehabilitation, Sport medicine and SporTs science) guidance. British Journal of Sports Medicine. 2021; 56(4): 175-195. doi: 10.1136/bjsports-2021-103987
9. Ebert JR, Webster KE, Edwards PK, et al. Current Perspectives of the Australian Knee Society on Rehabilitation and Return to Sport After Anterior Cruciate Ligament Reconstruction. Journal of Sport Rehabilitation. 2020; 29(7): 970-975. doi: 10.1123/jsr.2019-0291
10. DiSanti J, Lisee C, Erickson K, et al. Perceptions of Rehabilitation and Return to Sport Among High School Athletes With Anterior Cruciate Ligament Reconstruction: A Qualitative Research Study. Journal of Orthopaedic & Sports Physical Therapy. 2018; 48(12): 951-959. doi: 10.2519/jospt.2018.8277
11. Greenberg EM, Greenberg ET, Albaugh J, et al. Rehabilitation Practice Patterns Following Anterior Cruciate Ligament Reconstruction: A Survey of Physical Therapists. Journal of Orthopaedic & Sports Physical Therapy. 2018; 48(10): 801-811. doi: 10.2519/jospt.2018.8264
12. Hamill J, Knutzen KM, Derrick TR. Biomechanics: 40 Years On. Kinesiology Review. 2021; 10(3): 228-237. doi: 10.1123/kr.2021-0015
13. Glazier PS, Mehdizadeh S. Challenging Conventional Paradigms in Applied Sports Biomechanics Research. Sports Medicine. 2018; 49(2): 171-176. doi: 10.1007/s40279-018-1030-1
14. Phellan R, Hachem B, Clin J, et al. Real-time biomechanics using the finite element method and machine learning: Review and perspective. Medical Physics. 2020; 48(1): 7-18. doi: 10.1002/mp.14602
15. Ma J, Wang Y, Wei P, et al. Biomechanics and structure of the cornea: implications and association with corneal disorders. Survey of Ophthalmology. 2018; 63(6): 851-861. doi: 10.1016/j.survophthal.2018.05.004

16. Wang Y, Tan Q, Pu F, et al. A Review of the Application of Additive Manufacturing in Prosthetic and Orthotic Clinics from a Biomechanical Perspective. Engineering. 2020; 6(11): 1258-1266. doi: 10.1016/j.eng.2020.07.019
17. Morrison C, Huckvale K, Corish B, et al. Visualizing Ubiquitously Sensed Measures of Motor Ability in Multiple Sclerosis. ACM Transactions on Interactive Intelligent Systems. 2018; 8(2): 1-28. doi: 10.1145/3181670
18. Stein AM, Grupp SA, Levine JE, et al. Tisagenlecleucel Model-Based Cellular Kinetic Analysis of Chimeric Antigen Receptor–T Cells. CPT: Pharmacometrics & Systems Pharmacology. 2019; 8(5): 285-295. doi: 10.1002/psp4.12388
19. Luo L, Guo X, Zhang Z, et al. Insight into Pyrolysis Kinetics of Lignocellulosic Biomass: Isoconversional Kinetic Analysis by the Modified Friedman Method. Energy & Fuels. 2020; 34(4): 4874-4881. doi: 10.1021/acs.energyfuels.0c00275
20. Morone G, Cocchi I, Paolucci S, et al. Robot-assisted therapy for arm recovery for stroke patients: state of the art and clinical implication. Expert Review of Medical Devices. 2020; 17(3): 223-233. doi: 10.1080/17434440.2020.1733408
21. Yozbatiran N, Francisco GE. Robot-assisted Therapy for the Upper Limb after Cervical Spinal Cord Injury. Physical Medicine and Rehabilitation Clinics of North America. 2019; 30(2): 367-384. doi: 10.1016/j.pmr.2018.12.008
22. Yamada K, Iwasaki N, Sudo H. Biomaterials and Cell-Based Regenerative Therapies for Intervertebral Disc Degeneration with a Focus on Biological and Biomechanical Functional Repair: Targeting Treatments for Disc Herniation. Cells. 2022; 11(4): 602. doi: 10.3390/cells11040602
23. Seo JH, Kim MS, Lee JH, et al. Biomechanical Efficacy and Effectiveness of Orthodontic Treatment with Transparent Aligners in Mild Crowding Dentition—A Finite Element Analysis. Materials. 2022; 15(9): 3118. doi: 10.3390/ma15093118
24. Avci T, Omezli MM, Torul D. Investigation of the biomechanical stability of Cfr-PEEK in the treatment of mandibular angulus fractures by finite element analysis. Journal of Stomatology, Oral and Maxillofacial Surgery. 2022; 123(6): 610-615. doi: 10.1016/j.jormas.2022.05.008
25. Onyibo EC, Safaei B. Application of finite element analysis to honeycomb sandwich structures: a review. Reports in Mechanical Engineering. 2022; 3(1): 283-300. doi: 10.31181/rme20023032022o
26. Barath Kumar MD, Manikandan M. Assessment of Process, Parameters, Residual Stress Mitigation, Post Treatments and Finite Element Analysis Simulations of Wire Arc Additive Manufacturing Technique. Metals and Materials International. 2021; 28(1): 54-111. doi: 10.1007/s12540-021-01015-5
27. Güvercin Y, Abdioğlu AA, Dizdar A, et al. Suture button fixation method used in the treatment of syndesmosis injury: A biomechanical analysis of the effect of the placement of the button on the distal tibiofibular joint in the mid-stance phase with finite elements method. Injury. 2022; 53(7): 2437-2445. doi: 10.1016/j.injury.2022.05.037
28. Banovetz MT, Roethke LC, Rodriguez AN. Meniscal root tears: a decade of research on their relevant anatomy, biomechanics, diagnosis, and treatment. Archives of Bone and Joint Surgery. 2022; 10(5): 366.
29. Wang C, Hou M, Zhang C, et al. Biomechanical evaluation of a modified intramedullary nail for the treatment of unstable femoral trochanteric fractures. Heliyon. 2024; 10(8): e29671. doi: 10.1016/j.heliyon.2024.e29671
30. van der Kruk E, Reijne MM. Accuracy of human motion capture systems for sport applications; state-of-the-art review. European Journal of Sport Science. 2018; 18(6): 806-819. doi: 10.1080/17461391.2018.1463397
31. Gohel V, Mehendale N. Review on electromyography signal acquisition and processing. Biophysical Reviews. 2020; 12(6): 1361-1367. doi: 10.1007/s12551-020-00770-w
32. DeKeyser GJ, Hakim AJ, O'Neill DC, et al. Biomechanical and anatomical considerations for dual plating of distal femur fractures: a systematic literature review. Archives of Orthopaedic and Trauma Surgery. 2021; 142(10): 2597-2609. doi: 10.1007/s00402-021-03988-9
33. Feng F, Liu M, Pan L, et al. Biomechanical Regulatory Factors and Therapeutic Targets in Keloid Fibrosis. Frontiers in Pharmacology. 2022; 13. doi: 10.3389/fphar.2022.906212
34. Duan C, Jimenez JM, Goergen C, et al. Hydration State and Hyaluronidase Treatment Significantly Affect Porcine Vocal Fold Biomechanics. Journal of Voice. 2023; 37(3): 348-354. doi: 10.1016/j.jvoice.2021.01.014
35. Willemsen K, Tryfonidou M, Sakkers R, et al. Patient-specific 3D-printed shelf implant for the treatment of hip dysplasia: Anatomical and biomechanical outcomes in a canine model. Journal of Orthopaedic Research. 2021; 40(5): 1154-1162. doi: 10.1002/jor.25133
36. Nordenholm A, Senorski EH, Westin O, et al. Surgical treatment of chronic Achilles tendon rupture results in improved gait biomechanics. Journal of Orthopaedic Surgery and Research. 2022; 17(1). doi: 10.1186/s13018-022-02948-2