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Biomechanical Analysis and Mobility Improvement of Auxiliary Mobile Equipment

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Abstract: As an advanced auxiliary mobile device, exoskeleton booster has attracted wide attention in the field of rehabilitation and life assistance. Through biomechanical analysis, this paper discusses the effect of exoskeleton booster on user mobility. Using biomechanical tools such as kinematics, dynamics and muscle mechanics, this paper deeply studies the influence of exoskeleton booster in different motion States, and verifies its biomechanical effect through simulation and experiment. Firstly, this paper analyzes the influence of exoskeleton booster on gait from the perspective of kinematics. The research shows that the exoskeleton booster can improve the walking efficiency of users by optimizing the step size and step frequency. The precise adjustment of joint motion by intelligent control system enables exoskeleton to better adapt to the gait characteristics of different users. Secondly, through dynamic analysis, this paper deeply studies the influence of exoskeleton on joint torque. The exoskeleton is designed to apply appropriate torque at key joints to help users complete the movement. The synergistic effect of this moment not only reduces the muscle burden of users, but also improves the stability of joints and reduces the risks in sports. In terms of improving mobility, exoskeleton technology can significantly improve the gait of patients in rehabilitation training, which is helpful to improve the balance ability of patients. The improvement effect of exoskeleton technology directly affects the quality of daily life of patients. This biomechanical effect provides strong support for the extensive application of exoskeleton technology in rehabilitation, sports assistance and daily life.

Keywords: Exoskeleton booster, Biomechanical analysis, auxiliary mobile equipment, mobility.

1. Introduction

With the continuous progress of science and technology and the development of human society, the demand for mobile devices has gradually increased, which has given birth to an urgent need to improve mobility. In this context, exoskeleton booster, as an innovative auxiliary mobility technology, has attracted more and more attention and research [1-2]. Exoskeleton booster not only shows great potential in the military field, but also shows a wide application prospect in many fields such as medical treatment, industry and daily life.

Biomechanics, as a scientific field of studying the structure and function of objects, provides a profound understanding and analysis of the ergonomic characteristics of mobile devices [3]. The purpose of this paper is to deeply analyze the kinematics and dynamics characteristics of exoskeleton booster from the perspective of biomechanics, and to explore its potential mechanism and effect in improving mobility. By discussing the interaction between exoskeleton booster and human biomechanics, we will reveal how exoskeleton technology can play a role in improving the performance of mobile devices, reducing the burden and improving user experience. Through in-depth study of the biomechanical characteristics of exoskeleton booster, we are expected to provide theoretical basis for designing more intelligent and effective mobile devices, and provide beneficial enlightenment for the future development of exoskeleton technology.

2. Biomechanical Basis

Biomechanics is a scientific field of studying the movement and mechanical behavior of objects, which covers many aspects, including kinematics and dynamics. By deeply understanding the structure, function and movement process of organisms, biomechanics provides a tool for quantitative analysis of the movement behavior of human body, animals or plants at the physiological and biological levels.

Kinematics focuses on the description of motion, including position, speed and acceleration. In biomechanics, kinematics studies the relative motion between parts of an object and the change of joint angles. Through kinematics analysis, we can reveal the movement mode and kinematics parameters of organisms. Dynamics studies the causes and effects of motion, involving concepts such as force, mass and acceleration [4-5]. In biomechanics, dynamic analysis can help to understand how the movement of organisms is driven by muscle strength and joint torque. This is helpful to understand the forces and moments in the movement of organisms.

Muscle is the core element in biomechanical research. The contraction and extension of muscles produce the movement of organisms. Muscle physiology studies the structure, function, physiological process and performance of muscles under different conditions. Biomechanics understands and quantifies the function of muscle through its mechanical properties [6-7]. Joint mechanics studies the structure, function and movement of joints. Biomechanics understands the angle change of joints in motion and the torque when working with muscles through joint mechanics analysis. This is helpful to understand how the skeletal system of an organism realizes complex motion patterns through joints.

Biomechanics not only has important applications in basic scientific research, but also plays an important role in the fields of medicine and engineering. For example, in medicine, biomechanics can be used to study dyskinesia and rehabilitation; In engineering, the principles of biomechanics are applied to the design and improvement of medical equipment, sports equipment and industrial machinery.

3. Biomechanical Analysis of Exoskeleton Booster

3.1. The design structure of exoskeleton booster and the coordinated movement of human joints

Exoskeleton booster, as a new auxiliary mobile device, aims to assist and enhance the user's sports ability through the combination of mechanical structure and electronic control system [8]. The design structure of exoskeleton booster is the basis to realize its function. Design structure usually includes mechanical frame, sensor, actuator and electronic control system.

Mechanical frame provides a supporting and connecting frame, usually made of lightweight materials to ensure the comfort and mobility of users. The sensor system is a sensor used to sense the user's motion intention, environmental information and external force. These sensors can include gyroscopes, accelerometers, pressure sensors, etc. [9-10]. The actuator provides mechanical auxiliary force to adjust the motion state of the exoskeleton according to the feedback from the sensor. Motor and hydraulic system are common actuators. The electronic control system integrates the sensor data, controls the movement of the actuator, and adjusts the working state of the exoskeleton according to the user's needs. Intelligent algorithm and human-computer interaction interface are its important components.

Angular velocity:

$$\omega = \frac{\Delta\theta}{\Delta t} \tag{1}$$

Where ω is the angular velocity, $\Delta\theta$ is the change of joint angle, and Δt is the corresponding time change.

Newton's second law:

$$F = m \cdot a \tag{2}$$

Where F is the force, m is the mass and a is the acceleration. This formula is used to describe the relationship between the force exerted by the exoskeleton and the acceleration of the user.

Torque:

$$\tau = t \cdot F \tag{3}$$

Where τ is the torque, r is the length of the lever arm, and F is the force acting on the joint. Used to describe the moment produced by exoskeleton at joints.

In order to optimize the design of exoskeleton booster and promote coordinated movement, the following factors should be considered: the man-machine interface design provides an intuitive and user-friendly interface, so that users can easily control the movement of exoskeleton. Adaptability and Comfort The design structure should adapt to different users' body shapes and sports needs, and ensure that the wearer feels comfortable during use. Real-time response emphasizes the real-time response of exoskeleton booster to user actions to maximize user experience and performance.

3.2. The assistance and adjustment of exoskeleton to human muscle strength in different motion States

Exoskeleton booster, as a cutting-edge technology, plays an important role in assisting and regulating human muscle strength in different exercise States. Its design aims to help and enhance the muscle strength of users, improve exercise efficiency and reduce the burden through intelligent mechanical structure and biofeedback system.

Energy and power calculation:

$$W = \int F \cdot dx \tag{4}$$

Where W is work, F is force and dx is displacement in the direction of force. Used to describe the work that the exoskeleton does to the user's movement.

$$P = \frac{dW}{dt} = F \cdot v \tag{5}$$

Where P is power, dW is slight change of work, dt is time change, F is force and v is speed. Describe the power that the exoskeleton exerts on the user per unit time.

In the exercise state of bearing and carrying loads, the exoskeleton reduces the muscle burden of users by supporting part of the loads. This is especially important for military and industrial applications that need to carry loads for a long time. Exoskeleton can help the user to complete the joint movement by applying extra torque at the joint. This is helpful to reduce joint load and improve exercise efficiency in walking and climbing. Under different terrains and slopes, the exoskeleton booster provides extra support through intelligent force distribution and adjustment, making it easier for users to adapt to different sports environments.

Exoskeleton booster can know the user's exercise intention in real time by monitoring the user's EMG signal, that is, the electrical signal of muscle activity. This enables the exoskeleton to adjust the assistance level according to the user's physiological state, and realize more personalized assistance. Exoskeleton can be analyzed according to the user's gait pattern, provide reasonable assistance to optimize the pace, and coordinate with the user's pace frequency and stride length to improve the fluency and stability of walking.

When walking and running, the exoskeleton booster provides assistance by applying torque to key joints, which makes it easier for users to complete gait and reduce the load of lower limb muscles. In uphill exercise, the exoskeleton can provide extra help to overcome gravity, while in downhill exercise, it can help users keep balance by adjusting the pace and slowing down the speed. In the scene of carrying loads, the load support function of exoskeleton can significantly reduce the burden on users and prolong endurance.

4. Effect of Exoskeleton Booster on Mobility

4.1. Biomechanical effect of exoskeleton booster

Exoskeleton booster helps to improve the walking efficiency of users by optimizing their gait patterns and

providing extra strength support. Exoskeleton booster can intelligently adjust the step length and step frequency to make it more in line with human physiological characteristics, thus improving the stability and speed of walking. Some exoskeletons are designed with energy recovery system, which can capture and store energy during the user's walking and then release it when needed, thus reducing energy consumption and improving walking efficiency. Figure 1 shows the biomechanical effects of exoskeleton booster in terms of step length, step frequency and speed, and provides an intuitive understanding of its functions in improving walking efficiency, reducing burden and reducing fatigue of users.

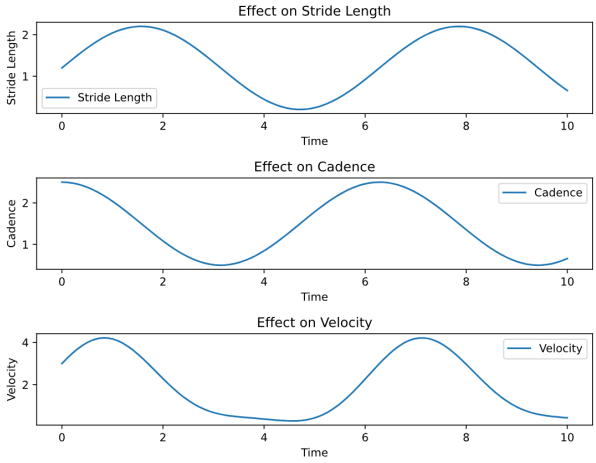

Figure 1. Biomechanical effect of exoskeleton booster

The first sub-picture shows the influence of exoskeleton booster on step size. Compared with the case without exoskeleton, it can be observed that the step size of exoskeleton booster is significantly increased at different time points. This shows that the design of exoskeleton is helpful to optimize the user's gait and make it cover the ground more effectively when walking, thus improving the walking efficiency.

The second sub-picture shows the influence of exoskeleton booster on step frequency. With the support of exoskeleton booster, the user's gait frequency is relatively high, especially in the early stage of exercise. This may mean that the exoskeleton helps to improve the user's movement speed and make the pace frequency faster, thus improving the walking efficiency to some extent.

The third sub-picture shows the influence of the exoskeleton booster on the overall speed. The introduction of exoskeleton booster significantly improves the speed of users, especially in the middle and late stages of walking. This shows that the auxiliary effect of exoskeleton is not only reflected in the improvement of step length and step frequency, but also directly reflected in the improvement of the overall walking speed of users, which further improves the walking efficiency.

Based on the information of the three sub-images, the biomechanical effects of exoskeleton booster in improving walking efficiency, reducing burden and reducing fatigue can be obtained. The increased step size and frequency and the overall lifting speed indicate that the exoskeleton booster can effectively assist the user to complete gait through reasonable mechanical design, and reduce the muscle burden of the user during exercise and improve the exercise efficiency. This biomechanical effect helps users to walk more easily and efficiently, reduces fatigue, and provides reliable biomechanical support for the promotion and application of exoskeleton booster in different application scenarios.

The exoskeleton booster is designed to share the burden of the user's body, especially in situations such as carrying heavy loads, walking for a long time or going uphill. Exoskeleton can support part of the load, share part of the gravity on the exoskeleton structure, and reduce the burden on users, especially for tasks that need to carry heavy objects or perform standing work for a long time. Exoskeleton helps the user to complete the exercise by applying torque at key joints, and reduces the muscle burden related to exercise. This is especially important for the elderly or those who have recovered from sports.

Exoskeleton booster has played an active role in reducing user fatigue. By reducing the burden and providing effective sports support, exoskeleton can reduce the fatigue level of users during long-term exercise or heavy-load work. Exoskeleton can help users to complete sports, share part of muscle burden, slow down the occurrence of muscle fatigue, and enable users to perform tasks more permanently. Part of the exoskeleton system provides posture support and balance adjustment, which helps to maintain the stability of users and reduce extra muscle effort caused by imbalance, thus reducing fatigue.

4.2. Effect of exoskeleton technology on improving mobility in rehabilitation training scene

As an innovative rehabilitation aid, exoskeleton technology has been widely concerned in patients' rehabilitation training field in recent years. Its unique mechanical structure and intelligent control system make it have excellent mobility improvement potential and provide more flexible and personalized rehabilitation training for rehabilitation patients.

In order to study the mobility improvement effect of exoskeleton technology in patients' rehabilitation training scene, the following experiments were designed in this study:

The experimental group used exoskeleton booster for rehabilitation training. The traditional rehabilitation training method in the control group was not supported by exoskeleton booster.

The independent variable among the experimental variables is the rehabilitation training time (in weeks). The dependent variable, that is, the patient's mobility, can be evaluated by the steps, pace and double support period in gait analysis.

The patients in the experimental group and the control group were tested for mobility before the start of rehabilitation training, every weekend and at the end of rehabilitation training, and the corresponding data were recorded. Figure 2 shows the experimental results.

The mobility of the control group improved in the initial stage of rehabilitation training, but it tended to be stable in the later stage. This trend reflects the decreasing influence of traditional rehabilitation training on patients' mobility after a certain stage or the training effect is gradually saturated. The mobility of the experimental group showed a trend of increasing gradually in the process of rehabilitation training. This shows that exoskeleton technology has a positive impact on patients' mobility in rehabilitation training, and helps patients to complete sports tasks better by providing extra

support and assistance.

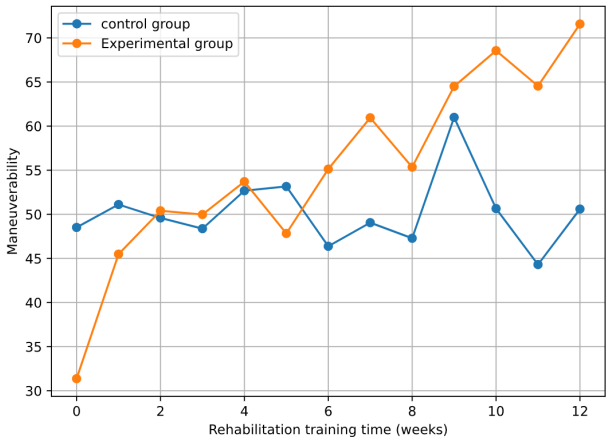

Figure 2. Experimental result

Exoskeleton technology has shown remarkable advantages in rehabilitation training, and compared with traditional rehabilitation training, patients' mobility has been better improved. This includes the increase of step size, the improvement of pace and the improvement of double support period. The improvement trend of the experimental group's mobility continues to increase, which shows that exoskeleton technology can produce more lasting effects in long-term rehabilitation training and provide better rehabilitation experience for patients.

Exoskeleton technique can significantly improve the gait of patients in rehabilitation training. Through the precise adjustment of joints by intelligent control system, exoskeleton can correct abnormal gait patterns of patients, provide stable support, and assist patients to walk more naturally. The improvement of mobility is not only manifested in the increase of step size and step frequency, but also in the smoothness of gait and adaptability to different terrain. This gait improvement has important clinical significance for rehabilitation patients such as stroke sequelae and spinal cord injury.

Exoskeleton technology is helpful to improve patients' balance ability in rehabilitation scene. By applying torque to key parts, exoskeleton can effectively support the patient's core muscles and reduce the burden of balance maintenance. At the same time, the intelligent control system of exoskeleton can sense the patient's body posture in real time and adjust it in real time, making the patient more stable when standing and walking. This is very important for balance training in the rehabilitation process of patients with stroke, lower limb fracture and so on.

The mobility improvement effect of exoskeleton technology directly affects the quality of daily life of patients. After training with exoskeleton, rehabilitation patients are usually able to carry out daily activities more autonomously, such as going up and down stairs and walking. The improvement of mobility not only brings physical improvement, but also enhances patients' psychological confidence, making them more actively participate in social and family activities, thus comprehensively improving the effect of rehabilitation treatment.

5. Conclusions

In this paper, the biomechanical analysis and mobility improvement of auxiliary mobile equipment, namely exoskeleton booster, are deeply studied. Through the analysis of kinematics, dynamics and muscle strength, and the discussion of the effects in different sports states, it is found that the exoskeleton can provide effective muscle strength assistance and adjustment in different sports states, which significantly improves the gait, balance and overall sports efficiency of users. Through the mechanism of gait optimization, load support and intelligent adjustment of joint torque, the exoskeleton booster not only improves the walking efficiency of users, but also significantly reduces the muscle burden and fatigue, creating a powerful condition for users to improve their mobility. Exoskeleton booster, as a cutting-edge rehabilitation and auxiliary mobility technology, is of great significance for improving user mobility and biomechanical effect. In the future research and application, we expect that through continuous innovation and technological progress, exoskeleton booster will better serve rehabilitation patients, the elderly and various demand groups, and bring greater improvement to human mobility and quality of life.

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