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The Current Development Status and Application Prospects of Lightweight Assistive Exoskeletons for People with Lower Limb Disabilities

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Abstract. In contemporary world, the lower limb disability group is gradually becoming a large group in society. As a chain reaction, lower limb exoskeleton robots are rapidly developing to meet the demand of patients with lower limb disabilities. Lower limb disability exoskeletons are making remarkable progress in multiple dimensions, including bionics, human-computer interaction, and artificial intelligence. Therefore, in today's distinctive lower limb exoskeletons, it is necessary to distinguish the target audience and suitable scenarios of different exoskeletons. This paper takes the light lower limb exoskeleton as the research object, reviews its current development status, studies the role it can play in the rehabilitation problems of the lower limb disabled population, and discusses its application prospects. The main work of this paper is to introduce the features of different exoskeletons and compare the advantages and disadvantages of those exoskeletons. Ultimately, this paper concludes that each exoskeleton has its own areas of expertise and needs to be properly applied.

Keywords: Exoskeleton, Rehabilitation, Lower limb robots

1. Introduction

Research and application of lower limb exoskeletons are developing rapidly to meet the needs of a growing population of people with lower limb disabilities. Lower limb exoskeletons significantly enhance human mobility and energy metabolism efficiency through lightweight design [1]. Among them, the lightweight exoskeleton stands out from the bulky, poorly portable and low-fit traditional exoskeleton with a series of features such as lightweight, high portability, low energy consumption and strong assistance effect, and has particularly significant development and application in the field of medical rehabilitation, such as the portable hip exoskeleton for stroke survivors, which significantly improves the gait stability of patients [2]. Liu Maomao and Han Ziyi are typical examples of scholars who have collected patients with subacute stroke and compared the rehabilitation effects of traditional therapy and exoskeleton-assisted gait training. Full-lower-extremity exoskeleton gait training can be employed to enhance the walking score, balance ability and motor function of patients [3]. Shen Jun, Guo Zhengyang and other scholars have also constructed exoskeleton motion models to reduce the motion errors of patients; thus, they have made

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significant progress in exoskeleton self-balance and fall-prevention control techniques and provided a reliable technical path for assisting disabled people in walking safely [4]. Therefore, nowadays, it is necessary for people who wish to make proper use of exoskeletons to learn about various kinds of lightweight assistive exoskeletons and know the strengths and weaknesses of different types of exoskeletons. Based on the present situation of lightweight exoskeletons in the field of sports rehabilitation, this paper will review the current development status of lightweight exoskeletons, objectively assess their strengths and weaknesses, and discuss their future application prospects.

2. Introducing lightweight exoskeletons

Lightweight exoskeletons specifically refer to wearable, lightweight human-machine collaborative mechanical devices weighing less than 20 kilograms. In recent years, it has brought about huge revolution in industrial sector, military, medical care and other fields with its ability to work far beyond far beyond that of human. It has provided strong support to various industries.

Billions of people around the world are suffering from the reality of losing their autonomy in life, being unable to exercise and lacking job opportunities, due to a variety of diseases (neurological, vascular, congenital malformations, etc.), traffic accidents and an aging population. For this reason, the lower limb lightweight assistive exoskeleton is designed for people with lower limb movement disorders. It aims to provide precise power assistance to the wearer's weak joints, make up for the wearer's lack of muscle strength and other problems, and help the wearer complete basic activities, thereby significantly improving the wearer's quality of life and autonomy.

2.1. Rewalk exoskeleton robot

The rewalk exoskeleton is a benchmark product for lower limb powered exoskeletons. The four parts of this system are the mechanical body, the sensing system, the power supply system and auxiliary devices. The main body has active rotational degree-of-freedom at both the hip and knee joints via the power drive unit, and these two joints can be driven independently to perform flexion and extension movements by outputting torque. A Structure can connect the joints and provide more freedom of movement for walking. For the motion control technology, an inertial sensor is used to determine when the centre of mass shifts, and then based on this change, the user's desire will be recognized. The four components of the Rewalk exoskeleton cooperate to achieve interlocking in their work. A tilt sensor determines how far the centre of mass of a person has shifted, and then a motor helps lift a leg, extends the knee, lands, and repeats this cycle according to the preset natural walking pattern of the main control chip, thus assisting people with weak lower limbs in walking. These structures help people with lower-limb disabilities who wear a rewalk exoskeleton perform daily living activities such as standing, walking, climbing and descending stairs, bending over, etc., and improve their quality of life.

The Rewalk exoskeleton is divided into rewalk personal and rewalk rehalibilitation. The personal version is focused on daily use, while the rehabilitation version is mainly used in clinical stages such as rehabilitation centers and hospitals. It can efficiently replace wheelchairs and help paraplegic people return to normal walking, and has broad application prospects in the field of medical rehabilitation. The advantage is that it can autonomously predict gait through tilt sensors, allowing patients to approach normal walking. However, the large overall weight of the device imposes certain limitations, making it difficult for patients to walk like a healthy person when wearing it. Also, it has no self-stabilization and requires the patient to maintain balance with the aid of the crutches, which poses a greater risk of falling.

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2.2. Step into bear-H1

The Maystep bear-H1 is a flexible actuated lower limb exoskeleton specifically designed for medical institutions. The Maystep exoskeleton is made of aerospace-grade aluminium alloy, carbon fiber and medical-grade flexible straps. The core structure consists of hip flexion and extension, knee flexion and ankle flexion and extension, and a hip rotation-assisted joint for achieving natural gait changes. It weighs about 20 kilograms on its own. But it innovatively uses the world 's first flexible drive as its core technology, replacing the rigid drive with a flexible drive output that is more in line with the natural movement laws of human joints, making the wearer feel less weight-bearing. It uses motors and elastic energy storage components to deliver power, which conforms to the force structure of the human body when the wearer walks, thereby reducing the pressure on the body caused by the rigid pull of traditional exoskeletons and making force control more stable and safer. At the same time, its structure can absorb part of its own weight and drop force, so that the wearer will not be noticeably aware of a 20-kilogram load. The gait exoskeleton uses AI to integrate detailed data such as motion angles, tension, and pressure captured by more than 30 sensors in real time to predict the wearer's movement intentions, thereby enabling the patient to exert force without lag, achieve movement, and help the patient recover.

Designed specifically for medical institutions, the Maxstep exoskeleton has multiple built-in functional modes that provide strong support for its extensive application in the field of sports rehabilitation. In the early stage, patients can complete a standard gait led by the exoskeleton in the passive mode, and then gradually switch to the active mode, assisted by the exoskeleton, allowing the patient's muscles to work on their own, enabling them to walk independently without the exoskeleton. At the same time, the exoskeleton can assess gait in real time, generate reports, upload them to the cloud, and assist in the hospital's treatment progress. It has the advantages of being body-sensing, safe, energy-efficient and cost-effective. But the lack of a personal everyday version of the Step robot limits its application range. And it has strict restrictions on height and weight, making it impossible for patients who are too tall, too short or too fat to wear the exoskeleton. At the same time, it is only suitable for patients with stroke, incomplete spinal injury, and complete paraplegia who cannot use it independently.

2.3. EksoNR

Ekso bionics Corporation (EksoNR) is a rigid-powered lower limb rehabilitation exoskeleton specifically designed for clinical rehabilitation. The core technology lies in the self-developed smartAssist adaptive assist algorithm, which can independently and continuously adjust the assist level of both legs in real time, gradually correcting abnormal patterns such as asymmetrical step size and insufficient hip and knee flexion [5]， to fit the injuries of hemiplegic and asymmetrical patients. The GaitCoach gait analysis and feedback system can be combined with multi-sensor data inside the exoskeleton to evaluate the gait treatment of patients in real time and alert medical staff, improving treatment efficiency, which is the core of its significant clinical application. In the clinical field, this exoskeleton is the only one that can cover four major neurorehabilitation center indications: spinal cord injury, stroke, acquired brain injury, and multiple sclerosis. Clinical studies have confirmed that the application of EksoNR in the rehabilitation period of patients with spinal cord injury is safe and feasible. It can significantly increase the standing time and step count of patients and provide an important basis for doctors to formulate treatment plans [6]. After EksoNR exoskeleton intervention in nineteen stroke patients, ICF functional scores and walking steps were significantly improved, and there were no adverse effects on the patients. However, the exoskeleton

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was limited to ground training and could not assist patients in recovering from actions such as climbing stairs. Moreover, the cost of materials, manufacturing, maintenance and training is high, and medical insurance coverage is not available to the majority of patients.

2.4. Indego lower limb exoskeleton

Indego lower limb exoskeleton (Ekso Bionics, formerly Parker Hannifin) is a lightweight, dual-scenario lower limb power exoskeleton for personal rehabilitation. The personal version weighs only 13 kilograms, making it one of the lightest exoskeletons on the market. The core technology of the Indego exoskeleton is a modular, quick-plug and self-wearable mechanical architecture. It innovatively features a five-module self-alignment design consisting of hip components and left and right thigh and calf modules, and achieves high-precision docking between the modules through quick-pull self-alignment clips [7]. The structure allows the patient to put on and take off the device independently in a sitting position in a wheelchair without assistance, significantly enhancing the portability of the device and the patient's ability to live independently, and getting rid of the reliance on clinical assistance.

The Indego exoskeleton has applications in both clinical rehabilitation and personal community fields. In the clinical field, it mainly helps patients with gait training, muscle strength reconstruction, nerve remodeling, and supports personalized assistive strength adjustment for patients with complete and incomplete paralysis. Its ability to support independent dressing and undressing makes it widely applicable in personal use, assisting users to walk independently on a flat surface on a daily basis and significantly improving their ability to take care of themselves. However, it currently only supports patients walking on flat surfaces and does not support complex terrains such as stairs and slopes, which imposes certain limitations on its application. Also, the assisted walking speed is slow, only allowing patients to complete activities within a limited community, still unable to help patients walk to complex places such as roads, leaving patients still unable to walk normally in society.

2.5. Cyberdyne hybrid assistive limb (HAL) exoskeleton system

Cyberdyne Corporation (HAL) is a medical-grade lower limb exoskeleton for people with severe motor dysfunction. The core technology is cybernics human-machine fusion control theory [8]. One of its core modules, CVC autonomous Intent Control, captures and decodes microvolt-level weak signals in real time through body surface sensors before muscle contraction, and initiates assist action with a response time of less than 100 milliseconds before the patient's muscle completes mechanical contraction [9], thus achieving precise synchronization of exoskeleton movement and the patient's intention and providing assistance without delay to the patient. In addition, the CAC autonomous gait control module automatically generates a stable gait in the absence of an effective electromyographic signal through the built-in bionic gait library and real-time trajectory generation function. The CAC and CVC modules switch autonomously, fuse dynamically, and are driven by the patient's mind when the electromyography signal is valid, and seamlessly switch to exoskeleton autonomous control when the signal is weak. This control mode differs from the passive control of traditional exoskeletons that rely on joysticks and buttons, allowing users to operate the device naturally and significantly enhancing the smoothness and user experience of human-machine collaboration.

HAL exoskeletons can assist patients in standing, walking, and going up and down stairs through the fusion of electromyographic intent drive and autonomous gait, restore their motor function, and

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improve the walking ability of patients with stroke, spinal cord injury, neuromuscular disease, sports injury, etc. It is currently widely used in the clinical field, with nearly 200 medical institutions worldwide using HAL exoskeletons, covering 80% of institutions in Japan. However, its waist-integrated lithium battery only supports two hours of battery life, which severely limits its development and makes it difficult to meet the daily long-distance mobility needs.

2.6. Re-store soft exo-suit

The Re-store soft exo-suit is a flexible exoskeleton developed by the Wiss Bio-Inspired Engineering Institute at Harvard University. The innovation lies in the fact that it abandons the traditional rigid frame and uses textile straps and cable structures, making the entire device weigh only three kilograms and allowing patients to wear it in five minutes, greatly enhancing comfort and portability when wearing the exoskeleton. It improves the symmetry of the patient's gait, enables unlimited free adjustment of assist intensity, and supports three training modes: assist, resistance, and free, playing a significant role in the patient's recovery process. According to clinical data statistics, the re-store exoskeleton can significantly increase the gait speed, step length and walking efficiency of stroke patients, reduce energy consumption and assist in gait recovery [10], but the range of power assistance for patients is limited to the ankle and foot of the human body, thus having obvious limitations.

3. Comparison of exoskeleton products

The designs of the above-mentioned exoskeletons are all focused on helping patients with lower limb disabilities with motor rehabilitation. To provide assistance to the patient, thereby improving the patient's gait during rehabilitation, enhancing the patient's walking ability, and helping the patient recover.

Table 1. Comparison of Exoskeleton products

Exoskeleton names	Control sensors	Structure	Application areas	The self-weight of the entire machine	Suitable for people
Rewalk	Center of gravity identification	Rigidity	Daily + medical institutions	About 27kg	Complete/incomplete paraplegia
Step into bear-H1	Center of gravity identification	Rigidity	For medical institutions	About 24kg	Spinal cord injury paraplegia
EksoNR	Center of gravity identification	Rigidity	For medical institutions	About 22kg	Paraplegia/stroke
Indego	Center of gravity identification	Rigidity	Daily + medical institutions	About 20kg	Mild to moderate paraplegia
HAL	Electromyographic signals	Rigidity	For medical institutions	About 30kg	Incomplete injury/stroke
Re-store soft	Center of gravity identification	Flexibility	Only for ankle assistance	Less than 5kg	Mild muscle weakness

As shown in Table 1, those exoskeleton have some similarities and differences.

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4. The application prospects and development of exoskeletons

Lightweight exoskeletons have broad application prospects in the field of medical rehabilitation. Besides medical rehabilitation institutions, exoskeletons can also assist patients with lower limb disabilities or middle-aged and elderly people with limited lower limb mobility in home or community Settings, enabling the integration of exoskeletons into life.

In terms of the future development trend of exoskeletons, current exoskeletons still have problems such as being bulky, inconvenient to wear, and having relatively low assistance. This means that patients can only perform simple activities in simple environments like communities when wearing exoskeletons, and they cannot support complex sports scenarios that require running, jumping, and other activities. In response to this, exoskeletons are moving towards lightweighting and comfort, allowing patients to use exoskeletons more comfortably to complete more activities. In terms of battery life, exoskeletons are currently moving towards longer battery life, increasing the time per use for patients. In terms of control, the exoskeleton uses electromyography to reduce latency to less than 100 milliseconds while maintaining the accuracy of intent recognition, gradually achieving low-freedom control for patients with human-machine integration. In the development of intelligent control, the exoskeleton can be combined with AI algorithms to calculate gait to make the patient's gait more and more in line with normal, and brain-computer interfaces are also being combined with the exoskeleton and entering the clinical field to achieve patient mind control. In terms of cost, with the large-scale development of exoskeletons, the scale effect has led to a significant drop in the cost of exoskeletons, allowing more and more ordinary patients to enjoy the benefits of exoskeleton assistance in their lives.

5. Conclusion

Lower limb exoskeleton robots can help people with lower limb disabilities move more easily and offer support for doctors during treatment at the medical rehabilitation stage. By comparing various brands of lower limb exoskeleton robots, this paper finds that each exoskeleton has its own strengths and weaknesses, and according to a person's specific needs, one should be chosen that is most suitable for that individual to achieve the desired therapeutic effect of the exoskeleton. At the same time, based on the analysis of each exoskeleton, it can be concluded that the development of exoskeletons still faces many problems, such as heavy weight, high cost, and difficulty in adapting to complex terrains, etc. To overcome the above problems and advance more rapidly, lightweight exoskeletons are changing in materials, design and structure, and are being combined with new technologies such as AI and brain-computer interfaces. Thus, exoskeletons can help patients perform movements that are similar to those of healthy individuals in complex environments and promote the construction of a barrier-free society for older people.

References

[1] Slade, P., Kochenderfer, M. J., Delp, S. L., et al. (2022). Personalizing exoskeleton assistance while walking in the real world. *Nature, 610*, 277-282.

[2] Pruyn, J., Murray, S., Gabert, K., et al. (2026). Hip exoskeleton reduces walking effort in stroke survivors. *Nature Communications, 17*, 1234.

[3] Liu, M. M., Han, Z. Y., Hou, J. X., et al. (2026). Effects of total lower extremity exoskeleton robots on balance ability and lower extremity function in patients with subacute stroke. *Journal of Rehabilitation, 1*, 1-8. (accessed 2026-06-26)

[4] Shen, J., & Guo, Z. Y. (2026). Research on motion planning and fall prevention control of self-balancing lower limb exoskeleton robot. *Henan Science and Technology, 9*, 25-29.

DOI: 10.54254/2753-8818/2027.KL39376

[5] Wiśniewska-Szurlej, A., et al. (2023). Enhanced rehabilitation outcomes of robotic-assisted gait training with EksoNR lower extremity exoskeleton in 19 stroke patients. *Medical Science Monitor, 29*, e938958.
[6] Gillespie, J., et al. (2023). Utilization of overground exoskeleton gait training during inpatient rehabilitation: A descriptive analysis. *Journal of NeuroEngineering and Rehabilitation, 20*, 102.
[7] Goldfarb, M., Farris, R. J., et al. (2014). Indego: A lightweight, modular exoskeleton for lower extremity assistance. *IEEE Transactions on Neural Systems and Rehabilitation Engineering, 22*, 744–752.
[8] Sankai, Y. (2009). Cybernic treatment with HAL for motor function disabilities. *Journal of Robotics and Mechatronics, 21*, 443–450.
[9] Sankai, Y. (2010). Voluntary control system of cybernics robot HAL. *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 4615–4620.
[10] Asbeck, A. T., et al. (2019). Soft wearable robotics for assistance and rehabilitation. *IEEE Transactions on Robotics, 35*, 873–889.