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Explore the Latest Advances in Rehabilitation Robots

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Abstract: With the continuous development of rehabilitation medicine and robotics, rehabilitation robot (RT) is also adapting to the development of the times and ushering in a new era of development. It has become a kind of emerging technologies and one of the important searching topics currently. With the deepening of multidisciplinary cross-disciplinary cooperation such as medicine and engineering, RT will need strong support from rehabilitation medicine theory and clinical experimental data and need to meet social rehabilitation needs. Existing RT equipment is mainly used for functional disorders of different parts of the body in the late stage of stroke and can be roughly divided into upper limb rehabilitation robot, hand function rehabilitation robot and lower limb rehabilitation robot. However, there is still a long way to go in the development of RT. In the future, researchers should focus on researching other robot-assisted technologies suitable for different diseases, different populations and different occupational fields.

Keywords: Rhabilitation robot, Upper limb rehabilitation-robot, Hand function rehabilitation-robot, Lower limb rehabilitation-robot.

1. Introduction

After ischemic heart disease and newborn diseases, stroke ranked as the third most common cause of death and disability worldwide in 2019 across all age groups. In that year, there were 143 million stroke-related disability-adjusted life years, 101 million prevalent strokes, and 12.2 million incident strokes [1]. According to the latest data, there are about 1.8 million new cases of stroke in China, and the incidence rate is increasing at a rate of 8.3% per year [2]. Stroke also has affected young people, which brings a huge burden to patients and the health system. At the same time, the number of rehabilitation therapists is scarce, and the skills are ragged. In order to make patients obtain more systematic and scientific rehabilitation effects, rehabilitation robots came into being. Rehabilitation robot (RT) can assist patients undergoing rehabilitation by using automation, intelligent equipment, and instruments [3]. RT is able to monitor and assess physiological status of patients in real time through the sensor. It tremendously increased the efficiency and safety of rehabilitation therapy [4]. It is now recognized as one of the global hotspots for robotics research. RT is now often employed in prosthetics and rehabilitation therapy, which not only advances the field of rehabilitation medicine but also stimulates the creation of new theories and technology in adjacent sectors [3]. There has been major breakthrough in the mechanism design, control, and experimental assessments of RT. However, in order to determine the therapeutic value of these robots, more objective quantitative evaluations must be carried out, more sensing techniques, and reference trajectory creation techniques must be

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created [5]. Based on the above statement, this paper will summarize potential application of RT. Tring to make curative effect of RT get more public attention. Hoping more and more people can devote themselves to this career.

2. Classification of rehabilitation-robot technique

So far, rehabilitation-robot can be roughly divided into therapeutic RT and auxiliary RT according to their purpose. Therapeutic RT can also be divided into exoskeleton robots and operational robots. They can assist patients with all kinds of dysfunctional rehabilitation therapies. Auxiliary RT can be fallen into robotic wheelchairs, intelligent prosthetics, robotic walkers and so on. These robots can assist patients with activities of daily living (ADL) [3]. And it can be also based on limb training parts, there are also three kinds of RT, upper limb RT, lower limb RT and hand function RT. But this paper focus on the second classification method.

Taking stroke for an example, "A clinical syndrome with rapidly developing symptoms that consist of a focal (or global, in a situation of coma) disruption of cerebral function that lasts more than 24 hours or leads to mortality without a known cause other than a vascular origin" is how the World Health Organization (WTO) defines stroke. In the world, stroke is the leading cause of disability and death [6].

2.1. Upper limb rehabilitation-robot

Upper limb injuries include any injury to the upper body, the most common ones are musculoskeletal injury and nerve injury, such as clavicle fractures, rotator cuff injuries, hand tendon ruptures, and sequelae of stroke and so on. These diseases will cause different levels of dyskinesia, so patients are difficult to finish ADL, such as dressing, eating, or using tools.

Kevin C. Tseng et al. have finished 9 studies including randomized controlled trials (RCTs), there is a meta-analysis on 8 of them. 295 patients were in the analysis. The Fugl-Meyer Assessment (FMA) was included in a meta-analysis of the literature, which was retrieved from the PubMed and other electronic databases. By contrasting the experimental group using the portable upper-limb rehabilitation robot with the control group using traditional therapy, the impact on upper-limb function before and after treatment in a clinical setting is examined. The outcome demonstrates the effectiveness of portable robots (FMA: SMD = 0.696, 95%CI 0.099~2.93, $p < 0.05$). Rehabilitating upper limb function is much enhanced when portable rehabilitation robot (PRR) is combined with conventional therapy. The results either match or surpass those obtained with traditional therapy alone. Therapists' labor intensity is reduced by robotic systems capable of handling labor-intensive and repetitive duties. This allows therapists to concentrate on providing more individualized rehabilitation sessions, which in turn reduces the workforce and boosts productivity [7]. In the future, robotic-assisted therapy devices will be employed more frequently in rehabilitation training because they may offer high-intensity and repetitive treatment to the damaged arm, which may improve upper-limb functional recovery in stroke patients [8].

2.2. Hand function rehabilitation-robot

As mentioned above, the vast majority of ADL belongs to fine motor skills, which require the participation of the upper limbs, and the recovery of fine motor depends on the recovery of hand function, such as muscle strength, skin sensation, balance and coordination function, etc., plus the extremely complex anatomy of the hand, so the rehabilitation of hand function should be more detailed and targeted. The traditional hand function rehabilitation treatment mainly relies on the empirical treatment of therapists and generally one-to-one or one-to-many manual operation. This method is not only time-consuming and labor-intensive, but also lacks of objective evaluation and

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real-time feedback analysis. It is difficult to accurately assess the degree and level of the hand dysfunction and the best treatment plan cannot be formulated [9]. There is a special type of RT called hand function RT.

Neha Singh et al. designed a type of electromechanical robotic exoskeleton in order to apply to the rehabilitation of wrist and metacarpophalangeal joints (MCPs). The Department of Neurology, AIIMS, New Delhi out-patient clinic screened more than 300 patients (n > 300) from 2016 to 2019 and they were all diagnosed stroke. The researchers randomly grouped the patients under two groups-Robotic-therapy Group(RG)and Control-Group(CG). The RG having therapy from robots and the CG received conventional physiotherapy training. The duration is both 45 minutes per day, 20 treatments per session (5 days per week, 4 weeks). In these data of Modified Ashworth Scale, Active Range of Motion and Full-Meyer scale and FM Wrist-/Hand component, RG showed significantly ($p < 0.05$) higher improvement than CG [10]. It further states that neurophysiological changes in RG are probable to be the result of plasticity recombination and use-dependent plasticity, so robotic exoskeleton training can improve cortical excitability and motor outcomes in stroke patients.

2.3. Lower limb rehabilitation-robot

Rehabilitation of lower limb injuries mainly involve neurological disease rehabilitation and orthopedic postoperative rehabilitation, such as rehabilitation from stroke, Parkinson, Guillain-Barré syndrome and hip or knee replacements, fracture of tibia and fibula, torn medial collateral ligament of the knee, Achilles tendon rupture and other postoperative rehabilitations. These injuries often accompanied by muscle atrophy, joint stiffness, adhesion and then mainly lead to abnormal walking function, thus affecting activities of daily living (ADL). In addition, the loss of independence to perform basic activities of daily living can bring developing secondary health conditions (SHC), such as cardiovascular and respiratory complications, bowel and bladder dysfunction, pressure ulcers [11,12]. Thus, restoring walking function is one of the main rehabilitation goals for patients [11]. So, this part mainly talk about robot-assisted gait rehabilitation (RAGT). RAGT assists in training the hip, knee and ankle joints of patients and simulating the normal human walking gait trajectory, so as to improve the balance of people with functional impairments [2]. Due to gait rehabilitation is a process, which is time-consuming, space-consuming, and labor-intensive. It is a challenge for therapist to involve in.

In 1994, Lokomat was first created to apply to gait rehabilitation. Since then, a variety of RTs have been created, which can be divided into three categories: wearable exoskeletons (like ReWalk, Ekso, and Indego), end-effector devices (like Gait Trainer, Haptic Walker), and grounded exoskeletons (like Lokomat, LOPES, and ALEX) [11].

There is an existing device called A3 lower limb robot. In order to examine how the A3 lower limb robot can enhance balance and lower limb walking skills in stroke patients, Lin-Jian Zhang et al. recruited 60 patients in the hospital and divided them into two groups, the A3 group performed 30 minutes of robotic walking exercise and the control group performed 30 minutes of routine walking exercise in addition to the standard 30-minute rehabilitation. Comparing brief-therapy effect on A3 group of gait robot combined with standard walking exercise in stroke patients, motor function and balance coordination can be improved. Through Stroke-Specific Quality of Life Scale, the scores of basic activities of daily living, Fugl-Meyer Assessment scores, FM balance meter, Stride speed, Stride length, Time Up and Go test and Rivermead Mobility Index in the two groups. It seems that adding A3 robotic walking exercise to standard physical therapy is more effective than adding ground walking exercise. (22.57 vs 4.07; 19.29 vs 3.52; 3.50 vs 0.96; 1.21 vs 0.18; 0.89 vs 0.11; 12.38 vs 2.80; 18.84 vs 3.80; 45.12 vs 8.41; 29.45 vs 8.68; 2.07 vs 0.41; $P < 0.05$). Furthermore, it may take some time for the effectiveness of the lower limb robot to become evident [13].

3. Conclusion

Once the dysfunction occurs, after the disease has stabilized, Patients must insist on rehabilitation every day, compared with traditional rehabilitation, the RT assists patients to complete physical rehabilitation actions and provide more targeted training. It is able to stimulate patients' consciousness and help patients to carry out neural reorganization or compensation. It can also generate new neuromotor function cells and establish the connection between limbs and brain nerve injury centers. So it is necessary to constantly explore RT assisted technology. Although rehabilitation robots are a promising method of rehabilitation, there are still many challenges.

In terms of RT itself, establishing clear applicable standards, evaluation methods, training methods, and safety standards for rehabilitation robots, make them widely used in hospitals and families. Setting parameters for different body parts of patients to achieve differential treatment and precise treatment. In the future, it is necessary to expand the most commonly used robotic rehabilitation training mode in clinical practice, combine multiple sensory systems for comprehensive monitoring and feedback, so as to obtain more accurate rehabilitation data, and take into account both unilateral and bilateral training modes, so as to explore rehabilitation robot systems based on different training modes. In order to compensate for the limitations of conventional clinical rehabilitation evaluation techniques, researchers have gradually introduced the technique of real-time quantitative data acquisition by sensors into the field of function evaluation as signal processing and capture technologies continue to advance, such as insufficient objective, quantitative and time-consuming.

For different ages, the elderly have difficulty in moving, and flexible and lightweight design should be the main line. Children's attention is easily distracted, so it should be more interesting and interactive. For different dysfunction, it can be tried to be applied to all kinds of diseases, such as abnormal muscle tone and posture in children with cerebral palsy (CP), abnormal respiratory function in patients with chronic obstructive pulmonary disease (COPD), etc. For different branches of rehabilitation, there are currently a number of cases of robots combined with physical therapy (PT), but there is a lack of clinical research on the combination of robotics and occupational therapy (OT), which combines robotic training with actual ADL to help patients complete specific occupational activities. It can also be combined with speech therapy (ST) to help children with CP and developmental delays restore swallowing and language functions.

In terms of RT prospects, for different regions, to give as many people as possible the opportunity to enjoy the value of RT, especially remote areas of China have backward economic development and inconvenient transportation, so RT should be promoted in the direction of low cost and high efficiency to be close to the daily life, life and work of patients.

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