Case Report

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COPD 재활에서의 균형 훈련을 위한 착용형 로봇의 효과

조 한 얼

연세대학교 의과대학 재활의학교실 및 연세대학교 희귀난치성 신경근육병 재활연구소

The Benefits of Wearable Robotics for Balance Training in COPD Rehabilitation

Han Eol Cho, M.D.

Department of Rehabilitation Medicine, Gangnam Severance Hospital, Rehabilitation Institute of Neuromuscular Disease, Yonsei University College of Medicine, Seoul 06273, Korea

Abstract

Chronic obstructive pulmonary disease (COPD) often leads to muscle weakness and impaired balance, increasing fall risk. This case study investigates the impact of wearable robot-assisted exercise on balance improvement in a 75-year-old male with COPD, bronchiectasis, chronic kidney disease, and bilateral carpal tunnel syndrome. The intervention involved eight sessions of robot-assisted gait training over one month, utilizing the Angel Legs M20 (ANGEL ROBOTICS Co., Ltd., Seoul, Republic of Korea) exoskeleton. Pre-treatment assessments showed severe functional limitations and significant difficulty in stair climbing. Post-treatment, the patient demonstrated improved muscle strength and balance. Notably, the patient showed enhanced control while sitting down and reduced stair climbing time without rest. These findings suggest that wearable robotics can significantly enhance balance and functional capacity in COPD patients, offering a promising adjunct to traditional rehabilitation.

Key Words

Chronic obstructive pulmonary disease, Wearable robotics, Balance training

Introduction

Chronic obstructive pulmonary disease (COPD) is a prevalent and progressive respiratory disorder characterized by airflow limitation, leading to breathing difficulties, reduced exercise capacity, and impaired quality of life [1]. In addition to the respiratory symptoms, COPD can also lead to muscle weakness and impaired balance. This can increase the risk of falls, which can be a major cause of serious complications such as femur neck fractures and death in older adults [2]. Traditional pulmonary rehabilitation focuses on improving respiratory function

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Corresponding author: Han Eol Cho, M.D.

Department of Rehabilitation Medicine, Gangnam Severance Hospital, Yonsei University College of Medicine, 211, Eonju-ro, Gangnam-gu, Seoul 06273, Korea

Tel: +82-10-2019-3500, E-mail: wtzephyr@yuhs.ac

and general physical fitness. However, advancements in technology, such as wearable robots, offer innovative approaches to enhance rehabilitation outcomes [3]. This case study investigates the effects of using a wearable robotic device to improve balance in a COPD patient.

Case Report

A 75-year-old male patient diagnosed with COPD, bronchiectasis, chronic kidney disease stage 5, and bilateral carpal tunnel syndrome presented for initial assessment. The patient reported persistent fatigue, increasing difficulty in walking despite efforts to exercise regularly, difficulty using his hands, which made it hard to walk with a cane, and trouble removing excessive airway secretions.

1) Pre-treatment Condition

To evaluate the patient's condition, several tests were performed, including manual muscle testing (MMT), the Short Physical Performance Battery (SPPB), a stair climbing test, and the 6-minute walk test (6MWT). For the stair climbing test, the patient was timed while ascending a flight of 12 stairs, with permission to hold onto the railing if necessary to prevent falls. During the initial assessment, the stair climbing test revealed that the patient required 1 minute and 30 seconds to climb a flight of stairs, needing to rest midway. The patient exhibited reduced respiratory function, decreased cardiopulmonary endurance, and severe carpal tunnel syndrome, which limited the use of walking aids. The 6MWT showed a walking distance of 200 meters, significantly below the average for his age group, indicating reduced exercise capacity. MMT scores indicated a reduction to grade 3/5 in hip extensors and quadriceps. The SPPB score was 4 out of 12, reflecting severe balance impairment. The patient also showed difficulty controlling his descent into a chair, often dropping heavily.

2) Intervention plan with wearable robot exercise

The intervention plan for the patient included basic COPD rehabilitation treatments such as aerobic exercise, resistance exercise, and respiratory retraining. Additionally, exercises using a wearable robot were incorporated to enhance lower limb muscle strength and balance training. For the exercise training assisted by a wearable robot, the study employed the Angel Legs M20 (ANGEL ROBOTICS Co., Ltd., Seoul, Republic of Korea) (Fig. 1). This exoskeleton robot, which operates untethered and weighs 19.5 kg, helps generate joint torque by detecting the gait phase through sensors located under the feet. The actuators in the robot can produce both bending (flexion) and straightening (extension) forces at the hip and knee joints. A computer housed in a backpack controls the device, allowing it to partially support the user's body weight

Fig. 1. Wearable exoskeleton robot used in this study.

during the stance phase by providing extension forces at the hip and knee and to aid the leg's motion during the swing phase by applying flexion forces. Before starting over-ground gait training, the patient performed specific exercises while wearing the wearable robot. This included weight shifting, squat exercises, and box step-ups, each performed for 30 repetitions in 3 sets. The patient then underwent over-ground robot-assisted exercise training. The total training time was 30 minutes per session, with 8 sessions conducted twice a week under the supervision of a physical therapist.

3) Post-treatment Condition

After one month of intervention, consisting of eight sessions of robot-assisted exercise training, several improvements were observed in the patient's physical performance and functional capacity. The MMT showed an improvement in the strength of the hip extensors and quadriceps from grade 3/5 to grade 4/5. Despite these improvements in muscle strength, the SPPB score and the 6MWT distance showed no significant change. However, the patient showed an increase in the Berg Balance Scale (BBS) score from 42/56 to 45/56, particularly in the sitting down from a standing position domain. Before training, the patient would drop heavily into the chair without control, but after training, he could control his descent and sit down slowly. This improvement significantly reduced his risk of falls.

In the stair climbing test, the patient's time decreased significantly from 1 minute and 30 seconds, requiring rest, to 34 seconds without any rest breaks, demonstrating improved lower limb strength and endurance. Before training, the patient could only ascend the stairs one step at a time, but after training, he could climb reciprocally and showed a significant improvement in his posture while climbing, with a notable reduction in the hunched position. The patient also reported subjective improvements in functional activities such as stepping over curbs, sitting down slowly, standing up from the floor, and climbing stairs unaided. Overall, the patient expressed a high level of satisfaction with the treatment.

Discussion

The use of wearable robotic devices in the rehabilitation of COPD patients presents a promising advancement in enhancing balance and overall functional capacity. This case study demonstrates significant improvements in the patient's muscle strength, balance, and daily functional abilities after one month of wearable robot assisted training. The incorporation of a wearable robotic device allowed for targeted and intensive training, which may not be achievable through conventional rehabilitation methods alone.

The notable improvements in the patient's balance, as evidenced by the increased BBS scores and the ability to climb stairs without rest, highlight the potential of wearable robots to address one of the critical issues faced by COPD patients: fall risk. Falls are a major concern for COPD patients due to muscle weakness and balance deficits [4]. The robotic device provided support and stability, allowing the patient to engage in exercises that specifically targeted balance and weight-bearing activities [5]. Moreover, the patient's feedback indicates a substantial enhancement in the quality of life. Being able to perform daily activities independently, such as stepping over curbs and climbing stairs, significantly impacts a patient's confidence and reduces the reliance on caregivers. The ability to participate in a family trip without assistance further underscores the psychosocial benefits of improved physical function.

One interesting result is the significant improvement observed after just eight short sessions over one month. This suggests that the robot-assisted exercise training, particularly the targeted therapy involving squats and box step-ups, was highly effective. For patients with severely impaired function who cannot support their own body weight, the use of a robot to assist with weight distribution

can be extremely beneficial, as demonstrated in this case.

The case suggested that wearable robots can complement traditional rehabilitation programs, offering a multifaceted approach to managing COPD-related impairments. While this case study focuses on a single patient, the positive outcomes warrant further investigation with larger sample sizes and diverse populations to validate the efficacy of wearable robotic devices in COPD rehabilitation. Long-term studies are also necessary to determine the sustainability of the improvements observed.

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