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Telerehabilitation Approaches in Pulmonary Rehabilitation Practices

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ABSTRACT
Chronic respiratory diseases (CRDs) are a major public health concern globally, presenting significant social and economic challenges for individuals and communities. With the advancement of technology, modern rehabilitation approaches for CRDs have begun to include telerehabilitation applications. Telerehabilitation approaches in pulmonary rehabilitation are crucial for maintaining treatment continuity and enhancing participation in CRDs, which are characterized by a significant disease burden and a requirement for long-term rehabilitation. While there are studies examining the application of telerehabilitation in pulmonary rehabilitation for respiratory diseases, the majority of these studies focus on a single disease. Research addressing different telerehabilitation methods across various chronic respiratory conditions is limited. This article aims to summarize the most current approaches to telerehabilitation for chronic respiratory diseases.

Keywords: Chronic respiratory diseases; pulmonary rehabilitation; rehabilitation; telerehabilitation.

Pulmoner Rehabilitasyon Uygulamalarında Telerehabilitasyon Yaklaşımları

ÖZ
Kronik respiratuar hastalıklar (KRH), dünya genelinde önemli bir halk sağlığı sorunu olup, bireyler ve topluluklar için önemli sosyal ve ekonomik zorluklar ortaya çıkarmaktadır. Teknolojinin ilerlemesiyle, KRH'lar için modern rehabilitasyon yaklaşımları telerehabilitasyon uygulamalarını da içermeye başlamıştır. Pulmoner rehabilitasyonda telerehabilitasyon yaklaşımları, önemli bir hastalık yüküne sahip ve uzun süreli rehabilitasyon gerektiren KRH'larda tedavi devamlılığını sağlamak ve katılımı artırmak açısından kritik öneme sahiptir. Respiratuar hastalıklar için pulmoner rehabilitasyonda telerehabilitasyon uygulamalarını inceleyen çalışmalar bulunsa da, bu çalışmaların çoğu tek hastalığa odaklanmaktadır. Farklı kronik solunum yolu hastalıklarında çeşitli telerehabilitasyon yöntemlerini ele alan araştırmalar sınırlıdır. Bu makale, kronik respiratuar hastalıklar için telerehabilitasyona yönelik en güncel yaklaşımları özetlemeyi amaçlamaktadır.

Anahtar Kelimeler: Kronik respiratuar hastalıklar; pulmoner rehabilitasyon; rehabilitasyon; telerehabilitasyon.

INTRODUCTION

Chronic respiratory diseases (CRDs) are a significant public health issue worldwide, posing substantial social and economic burdens on individuals and communities (1). The Global Burden of Disease Study reported that in 2017, 545 million people were affected by CRDs, with 50% of patients diagnosed with chronic obstructive pulmonary disease (COPD) (2). Pulmonary rehabilitation is a comprehensive intervention that includes patient-specific therapies aimed at promoting long-term adherence to rehabilitative behaviors for individuals with CRDs, encompassing exercise, disease management, education, and behavior change (3). A review of the current literature in pulmonary rehabilitation reveals that advancements in communication and software technologies have led clinicians to adopt telerehabilitation based applications. According to a report published by the American Thoracic Society in 2021, new telerehabilitation program models have been introduced to increase access to and utilization of pulmonary rehabilitation worldwide (4).

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Evidence is emerging that telerehabilitation models for pulmonary rehabilitation are effective and sufficient compared to conventional treatment methods (5,6).

Telerehabilitation is the process of delivering rehabilitation services remotely using information and communication technologies (7). In recent years, telerehabilitation has emerged as a significant innovation in healthcare, driven by advancements in information technology (8). Telerehabilitation allows patients to access rehabilitation services through various communication technologies and digital platforms, while therapists can assess patients' conditions, implement treatment plans, and monitor progress (9).

Especially during the COVID-19 pandemic, social distancing measures and restrictions have been reported to accelerate the adoption and widespread use of telerehabilitation applications (7). In this context, it has been noted that video conferencing systems, mobile applications, and other digital tools facilitate the effective delivery of rehabilitation services in home settings (9). The advantages provided by telerehabilitation applications significantly enhance the accessibility, efficiency, and effectiveness of services. In particular, individuals living in rural and underserved areas can more easily access these services when the need to travel to healthcare centers is eliminated (10). Increased accessibility to smart technology also contributes to time and cost savings (11).

In telerehabilitation, applications can be delivered synchronously (live), asynchronously (recorded), or in a hybrid format (12). These approaches are detailed in Table 1.

Table 1. General approaches to telerehabilitation in pulmonary rehabilitation

Approach Type	Content
Synchronous (Live) Telerehabilitation	Enables real-time interaction between patients and healthcare professionals. This category includes video conferences and live chats.
Asynchronous (Recorded) Telerehabilitation	Patients follow training and exercise programs during time frames set by healthcare professionals. This method typically includes video recordings and e-learning modules.
Hybrid Telerehabilitation	Combines synchronous and asynchronous approaches. Patients engage in the rehabilitation process using both live sessions and recorded materials.

Telerehabilitation systems encompass various services in the fields of physiotherapy and rehabilitation, including monitoring, intervention, supervision, education, consultation, and counseling (13). These systems provide therapists with the ability to make adjustments based on real-time feedback, allowing for the objective collection of data and the creation of treatment plans tailored to the individual needs of patients. It has been observed that physiotherapists and other clinicians often turn to web-based telerehabilitation applications for treatment guidance and monitoring (14). Systematic reviews and meta-analyses have reported that telerehabilitation models for pulmonary rehabilitation are used to achieve key outcomes such as increased exercise capacity, reduced breathlessness, improved health-related quality of life, and decreased hospital admissions (6).

The World Health Organization emphasizes the need to develop comprehensive guidelines in collaboration with international associations such as the European Respiratory Society (ERS) and the American Thoracic Society (ATS) to enhance the effectiveness of telerehabilitation in pulmonary rehabilitation and address the lack of field-specific guidelines. Moreover, research indicates that telerehabilitation can be as effective as traditional face-to-face programs, provided that key components such as exercise training and education are maintained (15). It has been reported that the effects of pulmonary rehabilitation gradually diminish approximately 6 to 12 months after the completion of the program (3). The most likely reason for this is the lack of sustainability in pulmonary rehabilitation. Therefore, it has been suggested that effective strategies must be developed to maintain the benefits achieved through pulmonary rehabilitation by ensuring the continuity of the process and enhancing patient adherence (3,15).

This review aims to examine current telerehabilitation approaches in pulmonary rehabilitation practices. Additionally, it will present the successful and negative aspects of current digital technologies in telerehabilitation approaches in detail under various headings.

Digital Therapy Platforms and Live Monitoring Technology

Today’s technology provides the possibility of remotely accessing traditionally face-to-face pulmonary rehabilitation sessions. It has been noted that this technology offers access to rehabilitation for patients with pulmonary diseases who may struggle to attend in-person sessions due to various reasons, such as reduced exercise capacity, walking distance, breathlessness, and fatigue (5,9). Although online/offline therapy platforms and applications with live monitoring technology differ in usage, they share similar general objectives. This technology offers therapists various opportunities for synchronous assessment with patients, creating rehabilitation programs, prescribing exercises, tracking exercise, and providing patient education (7,16).

Numerous studies utilizing online therapy platforms for pulmonary rehabilitation patients can be found. In one study (17), patients with SARS-CoV-2 were included in a pulmonary rehabilitation program on an online therapy platform developed by the authors. Feedback from patients and clinicians at the end of the program indicated that patients found the online video conferencing system acceptable and safe, while clinicians noted that it alleviated their workload and that this application could continue as part of the delivery of pulmonary rehabilitation services in remote settings.

In another study (16), patients classified according to the stages of COPD participated in a 9-week online multidisciplinary pulmonary rehabilitation program. Patients engaged in online education and exercise

programs individually from their homes but at the same time. The authors noted that synchronous education and exercise programs for COPD patients at different stages were cost-effective and feasible in terms of pulmonary rehabilitation, but internet connectivity issues could restrict access to treatment.

While using these technologies, it has been highlighted that the patient's access to communication technology can affect their experience in accessing healthcare services. In a randomized controlled trial conducted with COPD patients (18), participants were divided into two groups: one received treatment on an online platform while the other participated in a traditional face-to-face pulmonary rehabilitation program. The results indicated that the 6-week online pulmonary rehabilitation program had no significant differences in six-minute walking distance and symptom scores compared to the traditional program, and that online therapy was considered safe and well-tolerated by patients. The lack of observed differences in outcomes compared to the traditional pulmonary rehabilitation group emphasized the importance of remote consultation regarding treatment participation and cost factors. It was noted that online therapy platforms could enhance the patient experience with a personalized counseling plan tailored to individual patients.

Mobile Applications and Smart Devices

In pulmonary rehabilitation, a wide range of online and offline smart device technologies can be encountered. Mobile health is defined by the World Health Organization as "medical and public health functions supported by mobile devices such as cell phones, patient monitoring devices, personal digital assistants, and other wireless devices" (19). Today, smartphones are used as a complement to medical healthcare, offering new opportunities for patients and clinicians in accessing healthcare, learning, self-management, and communication (20). It has been reported that mobile health applications in pulmonary rehabilitation are primarily used to address patients' needs related to "symptom management" (21).

One study (22) demonstrated that mobile health applications led to positive changes in self-management related to symptom management and treatment adherence during exacerbations of COPD and asthma. Another study (23) tracked exercise and chronic symptoms in patients with small cell lung cancer through a mobile application. The effects of an exercise program that varied according to patients' personal symptom entries on reducing chronic symptoms were investigated. According to the findings, the mobile application was effective in reducing symptoms such as breathlessness, fatigue, anxiety, depression, and pain.

In a study involving COPD patients (24), researchers developed a mobile health application that was paired with a prototype wearable sensor to objectively monitor patients' saturation, heart rate, and step count over 12 weeks. It was suggested that objective patient monitoring with applications and wearable sensors could be a feasible, easy, and low-cost option for clinicians in personalized exercise programs and symptom management. However, it was emphasized that the number of studies investigating the long-term outcomes of mobile health applications in patient monitoring should be increased.

A review examining mobile health applications in chronic respiratory diseases (21) indicated that mobile health applications are highly usable and valid for symptom management, self-efficacy, quality of life, and exercise tracking in obstructive respiratory diseases such as COPD and asthma, as well as in conditions like transplantation and cancer that indirectly affect the respiratory system, particularly in patients over the age of 50.

Wearable Devices and Sensor Systems

With advancements in technology, the use of wearable devices and sensor systems in pulmonary rehabilitation have made it possible to monitor and record real-time information about patients' physical performance (25). Wearable devices include various types of flexible sensors that can be integrated into textile fibers, clothing, elastic bands, or directly attached to the human body (25). The market value of wearable health technology, which was $29 billion in 2019, is projected to rise to approximately $200 billion by 2027 (26). There is a consensus that the increased prevalence of chronic respiratory diseases (CRDs) and the corresponding financial burden on the healthcare system can be mitigated by the widespread use of wearable technologies (26, 27).

In one study (28), a wristband was used to monitor exercise intensity and daily physical activity levels in patients with COPD. The energy expenditure (kcal) was compared between supervised and non-supervised exercise days, revealing no significant difference in energy expenditure between the two. These findings suggest that the wristband monitoring method motivates patients regarding exercise participation and energy expenditure in COPD.

In a retrospective study (29), lung cancer patients were divided into experimental and control groups during the preoperative period. The experimental group consisted of physically active patients monitored with sensor-enabled pedometers, while the control group included patients undergoing routine monitoring. According to the study findings, the experimental group showed significantly lower rates of postoperative atelectasis, pulmonary infection, hypoxemia, duration of postoperative oxygen therapy, duration of chest tube placement, and length of hospital stay compared to the control group.

A systematic review and meta-analysis investigating the effectiveness of wearable devices in COPD patients (30) indicated that wearable devices could be used to evaluate and improve physical activity, functionality, and symptom management. However, it was emphasized that the sole use of wearable devices might not be as effective as using them alongside rehabilitation programs supervised by clinicians, and that a more detailed examination is needed regarding the management of exacerbation periods in COPD.

Virtual Reality (VR) Therapy

In recent years, virtual reality (VR) technology has provided opportunities for managing lung diseases such as asthma, COPD, and lung cancer, as well as disorders related to anxiety and stress caused by these diseases. VR technology serves as a general term for virtual reality systems, including virtual reality games, augmented reality, and mixed reality (31). It is believed that VR technology has promising potential to encourage individuals' engagement with virtual reality systems by creating various environments that involve visual,

auditory, and/or haptic stimuli, thereby enhancing motivation and adherence to exercise programs (32).

VR therapies are frequently used in pulmonary rehabilitation to focus on "breathing" exercises (33). Traditionally, breathing therapy and relaxation training are taught under the holistic guidance of therapists and life coaches, but the increasing practicality of VR technologies is rapidly gaining importance. There is a general consensus that traditional breathing exercise devices, while low-cost, are inadequate in providing objective data and ensuring patient adherence (34). On the other hand, it has been reported that VR technology facilitates patient compliance by allowing individuals full control over the environments they are exposed to. Moreover, the use of biosensor technology, which provides acoustic, visual, and biological feedback, enables VR technology to offer users the ability to consciously and effectively monitor and control their experiences (35).

In one study, patients who developed persistent dyspnea following COVID-19 pneumonia were trained in respiratory control and breathing exercises using VR-assisted visual respiratory stimuli. The patients' respiratory comfort levels were assessed using a Likert-type scale after treatment. It was reported that their respiratory comfort levels increased compared to the control group, although there were no differences in objective respiratory data such as respiratory rate, heart rate, and saturation (36).

In another study, VR technology was incorporated into the weaning process from mechanical ventilation for patients with complete C4 spinal cord injuries. The practitioners noted that patients did not report negative feelings such as claustrophobia or nausea while experiencing the treatment. They also reported that VR could be successfully integrated into the pulmonary rehabilitation training protocol during the weaning process from mechanical ventilation in an acute rehabilitation setting following spinal cord injuries (37).

A comprehensive review suggested that VR could be an effective solution for pulmonary rehabilitation among lung cancer, COPD, and asthma patients, as well as addressing mental health issues related to anxiety associated with these diseases. Overall, the results of studies indicate that VR may enhance functional outcomes in pulmonary rehabilitation, increase body awareness in breathing, and improve relaxation techniques (34).

CONCLUSION

Chronic respiratory diseases (CRDs) represent a significant global health challenge, imposing extensive socioeconomic burdens on individuals, healthcare infrastructures, and broader public health systems. Pulmonary rehabilitation remains a cornerstone in managing CRDs, integrating multifaceted therapeutic strategies that encompass individualized exercise regimens, patient education, behavioral interventions, and disease self-management. The emergence of telerehabilitation as a technologically driven adjunct to traditional rehabilitation paradigms has revolutionized the accessibility and scalability of pulmonary rehabilitation. While telerehabilitation presents a compelling alternative, its ability to fully substitute conventional rehabilitation remains an area of ongoing investigation. This uncertainty is primarily due to a paucity of high-quality longitudinal comparative studies. Additionally, the heterogeneity of telerehabilitation models across healthcare systems necessitates a more granular approach to evaluating their clinical utility, cost-effectiveness, and adaptability across diverse patient demographics.

A growing body of evidence underscores the potential efficacy of telerehabilitation in enhancing exercise capacity, mitigating dyspnea, and improving health-related quality of life. Mobile health applications and wearable sensor technologies have demonstrated significant utility in optimizing patient adherence and enabling continuous physiological monitoring. Similarly, virtual reality (VR)-based rehabilitation has been shown to enhance patient motivation and psychological resilience, fostering a more immersive and engaging rehabilitation experience. Furthermore, telemonitoring systems allow real-time clinical assessment and adaptive modification of rehabilitation protocols, supporting a more dynamic and responsive approach to disease management. Nevertheless, the efficacy of these interventions is influenced by multiple factors, including disease severity, technological accessibility, and patient-specific determinants. Future research should further explore the personalization of telerehabilitation to optimize long-term clinical outcomes.

Despite these advancements, telerehabilitation is not without limitations. One major barrier to widespread implementation is the absence of standardized protocols and clinical guidelines, leading to inconsistencies in service delivery and patient outcomes. Digital disparities, including variations in technological literacy and internet accessibility, further compound challenges in ensuring equitable access. Moreover, the lack of direct supervision in remote rehabilitation settings may compromise the quality and safety of interventions, particularly for patients with severe multimorbidities or cognitive impairments who require more intensive clinical oversight. Additionally, the financial and infrastructural investments required to integrate sophisticated telerehabilitation technologies into existing healthcare systems remain a critical consideration, particularly in resource-limited settings where digital health infrastructure is underdeveloped.

This study differentiates itself from prior literature by adopting a comprehensive, multi-disease framework that extends beyond a singular focus on chronic obstructive pulmonary disease (COPD). Unlike previous research that predominantly examines telerehabilitation applications within isolated respiratory conditions, this review synthesizes evidence across multiple CRDs, offering a broader comparative perspective on the efficacy and limitations of various telerehabilitation modalities. Furthermore, this study provides a critical assessment of the clinical feasibility, operational barriers, and pragmatic challenges associated with integrating telerehabilitation into routine healthcare practice, an aspect often underexplored in prior studies. In particular, this review underscores the necessity of hybrid rehabilitation models that strategically integrate both remote and in-person rehabilitation components, thereby optimizing patient-centered care while maintaining the clinical rigor of traditional rehabilitation.

Future research should prioritize large-scale, methodologically robust randomized controlled trials that directly compare telerehabilitation with conventional rehabilitation across diverse patient populations. Additionally, further inquiry is required to delineate patient subgroups that derive the most significant benefit from telerehabilitation while identifying those for whom alternative rehabilitative approaches may be preferable. The development of hybrid rehabilitation frameworks that leverage the complementary advantages of both in-person and remote modalities appears to be the most viable trajectory moving forward, ensuring broader accessibility while preserving the individualized, high-quality care essential for effective pulmonary rehabilitation. Furthermore, continued exploration of the long-term sustainability of telerehabilitation—including comprehensive cost-effectiveness analyses, patient-reported outcomes, and the integration of artificial intelligence-driven adaptive rehabilitation models—will be instrumental in shaping its future role within pulmonary rehabilitation and respiratory disease management at large. By addressing these critical gaps, future studies can provide a clearer roadmap for optimizing telerehabilitation services, ensuring that these technologies not only enhance accessibility but also deliver meaningful clinical improvements for patients with chronic respiratory diseases.

Conflict of Interest

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