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REVIEW ARTICLE

Digital Health Care in Chronic Respiratory Diseases during and beyond the COVID-19 pandemic. A Critical Review

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Abstract

The coronavirus disease 2019 pandemic increased the need for alternative disease monitoring, medication management, and rehabilitation approaches. During this period, significant adjustments were made to integrate telemedicine into various aspects of healthcare.

This critical review describes the use and effectiveness of digital health approaches adopted for the care of people with chronic respiratory diseases during and beyond the COVID-19 pandemic. A thorough search was conducted in the PubMed database from January 2020 up to December 2022. A total of thirty studies were retrieved and reviewed for the utilization of telehealth services for education, monitoring, assessment, self-management, and rehabilitation in comparison to standard care or not.

During the lockdown patients with chronic obstructive pulmonary disease, asthma, cystic fibrosis, interstitial lung diseases, lung cancer, and neuromuscular disorders indicated positive perception towards remote healthcare delivery. They expressed high levels of satisfaction and achieved self-management in chronic obstructive pulmonary disease and asthma. Remote visits decreased exacerbations of asthma and reinforced smoke cessation in patients with chronic obstructive pulmonary disease. Teleassessment and monitoring increased the percentage of cystic fibrosis and Duchenne Muscular Dystrophy patients seen via telemedicine. Web platforms and mobile applications supported telehealth interventions to reduce stress, depression, and anxiety in patients with cystic fibrosis, assessed the quality of life and physical activity of patients with sarcoidosis, and pursued health education in adolescents with asthma. A few studies carried out telerehabilitation programs in patients with chronic obstructive pulmonary disease, cystic fibrosis, Duchenne Muscular Dystrophy, and sarcoidosis. Findings advocate the feasibility of online exercises, the improvement of exercise capacity, muscle strength, respiratory muscle strength, and the reduction of dyspnea and fatigue.

Keywords: asthma, COPD, cystic fibrosis, digital health, idiopathic pulmonary fibrosis, interstitial lung disease, lung cancer, neuromuscular diseases, sarcoidosis, telehealth, telerehabilitation

INTRODUCTION

The onset of the COVID-19 pandemic, as well as the containment measures implemented to limit the spread of the infection, had a significant impact on the global healthcare system. Many healthcare providers were forced to reconsider the way of assessing and managing respiratory diseases due to social constraints and difficulties in accessing rehabilitation services, resulting in a rapid shift from traditional care to telehealth. Innovative digital health solutions, particularly remote monitoring programs, emerged and evolved quickly to assist physicians, respiratory therapists, and other clinical care teams in managing high-risk respiratory patients within healthcare's "new normal"¹.

The term "digital health" refers to a broad range of solutions based on the use of information and communications technology (ICT), such as telemedicine and telehealth provided synchronous, asynchronous, or remotely monitored (consultations, monitoring, digital healthcare platforms, electronic health records, health apps, etc)². In this sense, telerehabilitation in pulmonary diseases employs a variety of technological modalities to improve healthcare services and the continuation of treatment³. Evidence shows that monitoring, managing, and rehabilitating pulmonary diseases via remote interventions is a safe and efficient model⁴. Telephone calls and videoconferencing are examples of digital tools used to deliver critical health components such as patients' physiological signs and symptoms. Such approaches also provide supervision and

feedback for exercise training as well as discussions about self-management education³.

Therefore, redesigning respiratory rehabilitation services has become critical in the management of chronic respiratory diseases (CRDs) during and beyond the coronavirus disease 2019 (COVID-19) pandemic⁵. This review describes the use of digital health approaches adopted for the care of people with CRDs during and beyond the COVID-19 pandemic. We focused on several studies delivered from January 2020 up to December 2022 to support healthcare interventions remotely provided to those patients who suffered from CRDs or from other diseases which cause respiratory limitations and symptoms. We briefly report the effectiveness of telemedicine in the education, monitoring, assessment, self-management, and rehabilitation of CRDs, starting with the most common respiratory diseases such as chronic obstructive pulmonary disease (COPD) and asthma, cystic fibrosis (CF), interstitial lung diseases (ILD), and lung cancer, as well as the neurological diseases that affect respiratory function.

METHODS

We conducted a critical review of the literature to describe the adoption of digital healthcare interventions, during the COVID-19 pandemic, on chronic pulmonary diseases. A comprehensive search was carried out in the PubMed database from the inception of 2020 to December 31, 2022, using English language literature to identify relevant articles. The search included a combination of

keywords mainly focused on “digital health”, “digital tools”, “remote rehabilitation”, “telemedicine”, “telerehabilitation”, “health care delivery”, “exercise”, “intervention”, “asthma”, “chronic obstructive”, “COPD”, “cystic fibrosis”, “interstitial diseases”, “pulmonary hypertension”, “lung cancer”, “neuromuscular diseases” and “pulmonary disease”. We examined full-text and open-access articles. Inclusion criteria included qualitative, quantitative, and mixed methods studies. The period of patient recruitment specifically covered the entire COVID-19 pandemic and beyond. No criterion was applied regarding participants’ age. Therefore, we included both adults and children. Furthermore, editorials, letters to the editor, reviews, and systematic reviews were not considered.

Therefore, this critical review included studies that investigated the use and effectiveness of telemedicine in the education, monitoring, assessment, self-management, and rehabilitation of CRDs and respiratory dysfunctions, compared to usual care or not. Thirty articles were retrieved through database searching after being evaluated for relevance.

Chronic Obstructive Pulmonary Disease

In patients with COPD, the COVID-19 pandemic has imposed serious barriers to the implementation of pulmonary rehabilitation in the outpatient setting while virtual care usage and telehealth have risen steeply in the last 3 years⁶. In a study conducted by the COPD Foundation in May 2020, the authors reported that 78% of patients with COPD had avoided

leaving their house since the beginning of the pandemic and more than half (64%) started using telemedicine for their healthcare⁷.

A Cochrane systematic review of telehealth in patients with COPD examined 29 clinical trials (5654 participants) all of those published in the pre-pandemic period (by April 2020), for the effects of remote monitoring alone (10 studies, 2456 participants) or in combination with the usual care (8 studies, 1033 participants) or multi-component interventions with remote monitoring or consultation (11 studies, 2165 participants) versus usual care alone. Analysis of the literature indicated low to moderate evidence about the effects of telehealth interventions compared to usual care when assessed for the risk of an exacerbation, dyspnea symptoms, hospital admissions, and hospital service utilization or death⁸.

Although the evidence about the effectiveness of remote monitoring plus usual care provided asynchronously is inconclusive, remotely implemented pulmonary rehabilitation (PR) programs are non-inferior to traditional center-based PR programs and have a greater effect on dyspnea symptoms and COPD Assessment Test scores than the usual care⁹. Therefore, clinicians in the early days of the lockdown and the pandemic took action to provide health-related support to patients with COPD as healthcare systems reduced drastically nonemergency in-person care services.

In early June 2020, took place predominantly only specific planned activities, such as gathering patients’ health information¹⁰, providing education, assessing

the impact of COVID-19 on patients' everyday life, assessing the ways the pandemic affected interactions with healthcare providers, and developing self-management plans (Table 1). Extended surveys for clinicians and patients with COPD were carried out in the UK, aiming to understand the scope and the support for remote care delivery and information gathering regarding the extent of their use of remote care modalities¹¹. The majority of the clinicians reported that they were able to assess symptom severity (95%), reinforce smoking cessation (84%) and oxygen therapy (80%), and support patients' self-management plans (80%). Notably, the majority of patients (58%) had a high agreement that remote communication helps to assess the severity of their symptoms. Similarly, in a later study by Arnaert et al.¹⁰, patients with severe COPD (GOLD group D) expressed their experiences and the potential benefits of receiving integrated telehealth services during the pandemic. Most participants were more concerned and anxious about their health due to their vulnerability to severe consequences within the COVID-19 context. They expressed that having their general practitioners on a telemonitoring system would be valuable in facilitating the continuity of care without feeling any fears about sharing their sensitive health data information. Furthermore, COPD patients felt confident to overcome any technical difficulties and acknowledge the effectiveness of a remote program¹² (Table 1).

The latest studies were part of larger prospective studies that evaluated the use of telemonitoring¹⁰, telerehabilitation, and

telecoaching¹² to enhance COPD patients' health-related outcomes. This highlights that the healthcare professionals had already been prepared to face and to further study telehealth services. Therefore, the pandemic isolation sparked the clinical and research activity in this field and allowed expansion to more robust interventions, such as home-based telerehabilitation³.

Acknowledging, the importance of delivering interventions that promote physical activity and improve functional performance in patients with CRDs, Lewis et al.¹² found significant physical and psychological improvements in 1 min sit-to-stand test, anxiety, depression, and respiratory-related quality of life, after a 6-week (9-12 sessions) online platform delivery home-based rehabilitation program.

Later on and during the pandemic, single-center-based telerehabilitation sessions were implemented with a variety of exercise types (aerobic, resistance exercises for the lower and the upper limbs, treadmill and bicycle exercises, respiratory muscle training, etc) (Table 1)^{13,14} mainly focused on patients with COPD who experienced more severe symptoms, such as greater dyspnea and/or more exercise and functional limitations^{10,12,14}. These sessions included those patients who had already participated in a face-to-face pulmonary rehabilitation program¹². Such interventions show that telerehabilitation may prevent the deleterious effects of the disease progression^{12,14}, such as the loss of functional capacity. Miozzo et al conducted two remote synchronous sessions per week from April 2020 to July 2021 for 18 patients with COPD

(Table 1). The authors found that the mean 6-minute walking distance decreased by 39 meters in those patients who participated in the remote telerehabilitation program and by 120 meters in the patients of the control group (n=14) who did not receive any care. Additionally, the benefits of mental health (74 ± 14 versus 64 ± 20 units, $p=0.02$) and social functioning (74 ± 21 versus 62 ± 27 units, $p=0.03$) were significantly greater in the telerehabilitation versus the control group after the intervention.

Similarly in patients with more severe COPD ($FEV_1\%=30 \pm 5$) (n=34), when daily respiratory muscle training was provided through a mobile phone application for 6 months, improved diaphragm mobility (pre-rehabilitation versus post-rehabilitation: 2.81 versus 3.44 cm, respectively), inspiratory (pre: 57.9 versus post: 73.2 cmH₂O) and expiratory (pre: 83.4 versus post: 95.0 cmH₂O) muscle strength¹⁴.

TABLE 1. Characteristics of the selected studies for patients with COPD

Authors/year of publication	Purpose	Study population/sample size/age, ys	Study design	Control group/sample size/age, ys	Intervention	Reported outcomes	Limitations
Arnaert et al (2022) ¹⁰	To explore COPD patients' experiences and the potential benefits of receiving telehealth nursing services	COPD / 10 / 71.5 ys (67-80)	Qualitative descriptive study	No CG	Semi-structured interviews, 60 to 90 minutes (June 2020)	Confident in the clinicians' availability and support during isolation time. Benefits of an oximeter use	The context of data collection; Participants suffered from varying levels of COPD severity and other comorbidities
Miozzo et al (2022) ¹³	To compare the outcomes of TR to those of UC among patients who previously participated in face-to-face PR programs	Bronchiectasis, ILD, PAH / COPD / 18 / 73.4 ys (7.4) TR	Quasi-experimental retrospective study	Bronchiectasis, ILD, COPD / 14 / 54.5 (8.7) UC	Telerehabilitation during COVID-19 pandemic isolation (2 sessions/week) (July 2020-July 2021)	After 1.5 years of isolation: 6MWD decreased by 120 m in CG, and by 39 m in the TR group (p=.02); SF-36 social functioning and mental health improved only in the TR group by 17 and 2 units, respectively	Sample heterogeneity; older CG with higher BMI; Small groups' size
Wu et al (2021) ¹¹	Clinicians' and patients' perceptions of the appropriateness of using remote delivery for specific healthcare activities	Clinicians and COPD / 55 and 19 / 25-74 ys	Online survey and a consensus-building process	No CG	Questionnaires; Two-round consensus-building process based on Delphi period not referred	Clinicians feel able to assess symptoms severity (95%), reinforce smoking cessation (84%), and other healthcare resources (80%). Patients: develop a self-management plan (74%), reinforce smoking cessation (81%), seek in-person care (72%), initiate a rescue pack (76%)	The responses may not be representative. The low number of participants
Lewis et al (2021) ¹²	To assess the feasibility and acceptability of an online platform delivery of PR	COPD, ILD, Asthma / 14 / 69.7 ys (10.7)	Mixed-methods approach Quantitative collection data for PR outcomes from online-PR participants; semi-structured interviews with PR staff (n=4) and participants (n=4)	No CG	2 sessions/week, 6 weeks period not referred	Significant changes in 1 min sit-to-stand, GAD, PHQ -9, CRQ (dyspnea, fatigue, emotion, mastery)	Limited external validity; No control group; The majority of the participants had already participated in some face-to-face PR sessions
Irina et al (2021) ¹⁴	To implement an RMT program supplemented through a mobile phone application PR program	severe COPD / 34 / 59.2 ys (6)	Experimental study	No CG	"Pneumocontrol" application daily/30 breaths using the Powerbreath device (after July 2020)	Improvement of MEP, MIP and diaphragmatic mobility (in cm)	Small sample size; bias for self-selected patients;

CG: control group; COPD: chronic obstructive pulmonary disease; CRQ: chronic respiratory questionnaire; ER: emergency room; GAD: generalized anxiety disorder; ILD: interstitial lung disease; MIP: maximum inspiratory pressure; MEP: maximum expiratory pressure; PR: pulmonary rehabilitation; PAH: pulmonary arterial hypertension; PHQ: primary health questionnaire; PR: pulmonary rehabilitation; RMT: respiratory muscle training; TR: telerehabilitation; UC: usual care; ys: years; 6MWD: 6-minute walk distance

Asthma

The main concern of the clinicians was to develop and promote therapeutic strategies to optimize symptom control for those patients with severe asthma since many non-compliant asthma patients made more effort to schedule medical visits during the COVID-19 pandemic¹⁵. As a result, significant reductions in severe asthma attacks have been reported, in primary care and in those patients who need hospital admissions¹⁶. Many asthmatic patients were satisfied with the use of telemedicine as an effective intervention for the prescription of their medications and consultation.

During the COVID-19 pandemic, remote home self-management programs have been proven to be as effective as in-hospital care in the risk of emergency department admissions for patients suffering from severe asthma¹⁷. In particular, Benfante et al. (2022)¹⁷ set up a specific algorithm for monitoring their patients' symptoms and exacerbations by using a mobile phone application and emergency phone calls.

The observational retrospective cohort study by Cvietusa et al. (2022)¹⁸ examined the extent to which patients received asthma care through a virtual channel and the effects of this transition on asthma outcomes, compared with the same period in 2019. Four care classification groups were examined in this study: (a) no care, (b) in-person only, (c) virtual care only, and (d) a mix of virtual and in-person care. During the first 8 months of the COVID-19 pandemic, 4,828 patients (62%) received integrated health care for

asthma whereas 2,977 received no care (38%). Of the group receiving clinician care for asthma, 1,952 (25%) received virtual care only, 1,792 (23%) received in-person care only, and 1,084 (14%) received a mix of virtual and in-person care for asthma. The level of health care for asthma decreased in all modes of care from 76.7% in April to 43% by October 2020 and shifted from an in-person mode to virtual care. Courses of prednisone and asthma exacerbations requiring urgent care, emergency department care, or hospitalization were all more common in those receiving a mix of in-person and virtual care. Compared to the pre-pandemic levels, there was a decrease in asthma exacerbations during COVID-19, largely reflected in a significant decrease in the prescription of oral corticosteroids. In comparing patients who had one or more exacerbations in 2019 with those who had one or more exacerbations during 2020, the mean number of total visits was equal. However, the portion of total visits that were virtual for this population increased from 13% of all visits before COVID-19 to 58% of all visits during COVID-19¹⁸ (Table 2).

In the study of Khan et al. (2021)¹⁹, fifty patients with severe asthma had telephone follow-ups to determine their satisfaction with telemedicine. Although thirty-one patients (57.4%) were satisfied when using telemedicine for asthma self-management, 10% of the sample was not satisfied with the simple model of telephone consultation without reporting another preferable mode. Thirty-eight participants (70.4%) did not need to intensify their treatment and none of the respondents were admitted to a hospital

during the COVID-19 pandemic and lockdown. A total of 12 participants (22.2%) self-medicated (i.e., took over-the-counter

treatment, started oral steroids, or both)¹⁹ (Table 2).

TABLE 2. Characteristics of the Selected Studies for patients with Asthma

Authors/year of publication	Purpose	Study population/ sample size/age, ys	Study design	Control group/ sample size/age, ys	Intervention	Reported outcomes	Limitations
Khan et al (2022) ¹⁹	To determine the satisfaction of patients with severe asthma and the impact of the COVID-19 lockdown	Severe asthma/ 48 elderly/ 46.7 ys (22-61)	Cross-sectional questionnaire-based survey study	No CG	Telephone model of telehealth survey (March 2020 to June 2020)	Participants (57%) satisfaction	Self-reported data can be associated with response bias; Small sample; External validity and generalizability may be restricted
Cvietusa et al (2022) ¹⁸	To assess changes from in-person to virtual care in patients with persistent asthma. Comparisons with before the COVID-19 pandemic	Asthma/ 7.805 adults/ 18-99ys	Observational retrospective cohort study	No CG	Patient-level information from the integrated healthcare delivery system, electronic health records (March to October 2019 and March to October 2020)	Users of virtual care were younger with fewer comorbidities and financial barriers. Exacerbations decreased. Asthma medication adherence increased slightly.	Not be generalizable to other health care delivery systems; Used only a clinician diagnosis of persistent asthma but no other criteria
Al Raimi et al (2022) ²²	To assess the effect of health education via a mobile application in promoting QoL among schoolchildren with asthma in urban Malaysia	Asthma/ 214/ Experimental group Males 44 (13-14 ys) Females 63 (15-16 ys)	Quantitative study quasi-experimental, pre-and post-intervention design	Asthma/ Males / 52 (13-14ys) Asthma/ Females /55 (15-16ys)	Pre-test / post-test, non-equivalent CG design (during the COVID-19 period)	QoL improved in both groups. Significant differences in QoL scores between groups.	Lack of randomization; Self-reported questionnaires Failure to install the application
Radhakrishnan et al (2022) ²³	Investigate experiences in attending comprehensive asthma education when delivered in person or the virtual setting	Asthma/ 100 patients and caregivers/ Patients 6.7 ys (1.2-17.0ys)	Qualitative study	No CG	Structured surveys and semi-structured interviews (April 2018 to October 2021)	Participants (65.2%) preferred the option of a virtual session over an in-person session	Lack of true randomization

CG: control group; QoL: quality of life; ys: years

Pediatric Asthma

A scoping review, including 25 publications from 2016-2021 with asthmatic children and adolescents, demonstrated that mobile health technology is well-suited for remote patient monitoring (RPM) in a patient's habitual environment. There have been fast-paced developments in mHealth-enabled pediatric RPM, especially during the COVID-19 pandemic, necessitating evidence synthesis²⁰. In this context, peak expiratory flow devices, portable electronic spirometers, portable exhaled nitric oxide measurements, and novel digital health tools such as smartphone microphone spirometers were the most commercially available to monitor asthma symptoms in children. These devices were also designed to download results onto mobile devices or computers, facilitating transmission to and monitoring by healthcare professionals. Some of these devices, such as portable spirometers, may be valuable for in-home monitoring, integrating virtual care with critical physiological data²¹.

A quasi-experimental pre-post intervention design by Al Raimi et al. (2022)²² examined the effect of health education via a mobile application in promoting the quality of life among schoolchildren with asthma in urban Malaysia during the COVID-19 era. A total of 214 students were participated randomly assigned into two groups. The control group received face-to-face health education, whereas the experimental group received health education via a mobile application. The authors found that health education via a mobile application promotes the quality of life among schoolchildren with asthma (Table 2).

Similarly, Radhakrishnan et al. (2022)²³ performed a multi-methods study using structured surveys and qualitative interviews to solicit feedback from patients and caregivers following participation in a comprehensive asthma education sessions delivered either remotely (n=48) or in-person (n=23), between April 2018 and October 2021. Both virtual and in-person delivered asthma education was equally effective for improving perceived knowledge and confidence for asthma self-management. Virtual education was considered safe and more convenient (Table 2).

Cystic Fibrosis

Cystic fibrosis (CF) centers were obliged to adopt telehealth services to safely evaluate and follow up with patients avoiding the risk of exposure and spread of COVID-19²⁴, as well as to monitor patients' health condition and their adherence to physiotherapy and physical activity²⁵. Carrying out physiotherapy sessions via teleconsultations and remote monitoring of patients appeared to be an advantageous strategy for delivering appropriate care and preserving the CF care model^{26,27}. Facing the impact of the COVID-19 pandemic on the dynamics of healthcare services provided to CF patients, the clinicians focused on the study of the acceptance of telehealth services by those patients. The use of web platforms for the transition from face-to-face clinic visits to telemedicine seems to be a feasible and participant-acceptable option, as it was reported in a study where 38 out of 63 CF adult stable patients participated in telehealth visits during the COVID-19

pandemic²⁸ (Tables 3a, 3b). In the United States of America (USA) an adult CF center's experience revealed a positive favorable toward telemedicine, with 100% of respondents believing that telehealth will expand access to care and 80% supporting future telehealth use at the CF center²⁹. Additionally, the majority of patients (90%) thought that telemedicine would have little or a favorable influence on their relationship with the CF treatment team²⁹. Also in the USA, other adult, pediatric, and affiliate CF care programs that were surveyed about telehealth use, between July 29 and September 18, 2020, and again between April 19 and May 19, 2021, revealed that telehealth services

were available for use in 97% of the programs. In the first survey period, 36% of patients received telehealth via video conferences, and 8% received care only by telephone contact. In the second period, only 15% of visits were via audio and video conferences. Pediatric programs were less likely to recommend telehealth than adults or affiliates (21% versus 37% or 41% of the programs, respectively)³⁰. The telehealth advocates highlighted as an advantage the increased accessibility and the prevention of infection transmission. However, according to all programs, the most significant barrier to patient engagement with telehealth was the lack of internet access³⁰.

TABLE 3a. Characteristics of the Selected Studies for patients with Cystic Fibrosis

Authors/year of publication	Purpose	Study population/ sample size/age, ys	Study design	Control group/ sample size/ age, ys	Intervention	Reported outcomes	Limitations
Compton et al (2021) ²⁶	To increase the percentage of CF patients who owned a home spirometer and were seen by telemedicine	CF/131/non mentioned	Single-center study	no CG	Spirometry monitoring (onset of the pandemic to March 2021)	The percentage of patients who owned a home spirometer and were seen via telemedicine increased	Single-center study
Holmes et al (2022) ³⁴	To determine the feasibility of a home-based RET program using virtual personal training and to observe the effects of completion on glucose metabolism, pulmonary function, body composition, and physical fitness	Adolescents/10/ 15.80 ± 2.20 ys	Feasibility pilot study	no CG	Home-based RET program via online videoconferencing consisting of 36 sessions, 3 times/ week for 12 weeks (during the COVID-19 pandemic period)	Small yet favorable changes in insulin secretion. Decrease in the fat percentage and increase in fat-free mass and fat-free mass index. Small, yet statistically significant increases in VO ₂ peak, VCO ₂ peak and ventilation	Small sample size
Graziano et al (2021) ³⁶	To pilot a Telehealth Psychological Support Intervention for patients and caregivers to reduce stress, depression, and anxiety	Adolescents, young adults (16)/ 22.5± 6.9ys parents (14)/ 37± 6.3ys	Pilot Study	no CG	4 individual telehealth “zoom” sessions lasting 30–40 min each, with a psychologist (March to May 2020)	Stress decreased from pre to post-testing. Reductions in depression for patients and parents but not anxiety. Feasibility and satisfaction were positive	Small sample size. A potential bias in the recruitment of participants. Short intervention
Compton et al (2020) ²⁸	To develop a standardized and sustainable process to transition from face-to-face clinic visits to telemedicine visits	63/non mentioned	Feasibility Study	no CG	A telemedicine visit through the Webex platform (during the COVID-19 pandemic period)	38 patients were seen by the multidisciplinary team	lack access to high-performance internet

CF: Cystic Fibrosis; CG: control group; RET: resistance exercise training; ys: years

TABLE 3b. Characteristics of the Selected Studies for patients with Cystic Fibrosis

Authors/year of publication	Purpose	Study population/ sample size/age, ys	Study design	Control group/ sample size/ age, ys	Intervention	Reported outcomes	Limitations
Kenis-Coskun et al (2022) ³⁵	To examine the effect of TR on the QoL, depression, and anxiety levels of children with CF and their caregivers' mood and anxiety levels	Children /14/ 9.8 ± 2.14 ys	RCT	Children /14/ 10.0 ± 1.64 ys	Exercise program 3 times per week via Zoom for 12 weeks (clinicaltrials.gov:NCT04683809)	RCADS score for anxiety and depression decreased in the exercise group. Significant changes in improvement in the body image in the TR group. Caregivers' anxiety and depression levels did not change significantly	Small sample
Beser et al (2022) ²⁴	To monitor the health and nutritional status of pediatric CF patients via telehealth services and to determine the level of anxiety in the patients and their caregivers	Children and their caregivers/144/ 8.9 ys	Prospective cross-sectional study	Patients with upper respiratory tract infection or vaccination and their caregivers/49/ 9.2 ± 2.1 ys	Telehealth services to contact patients (March 11 to December 1, 2020)	Telehealth services reduced CF patients' and caregivers' anxiety. CF patients significantly improved their nutritional status	not reported
Costa et al (2022) ²⁷	To describe the experience of implementing teleconsultations in respiratory physiotherapy	184 (137 children and 47 adolescents) / 7.2±5.3ys	Cross-sectional, descriptive study	no CG	Teleconsultations by videoconference or telephone. (March to December 2020)	83.2% participated in the telemedicine service	not reported
Jaclyn et al (2021) ³¹	To understand how patients and their families experienced the shift to telehealthcare delivery	CF adults (120) and caregivers(141) 18 ys and greater	Cross-sectional study	no CG	Two surveys were disseminated electronically via email/text to all participants who completed a telehealth visit (April to June 2020)	77% of adults and 72% of pediatrics were highly satisfied with telehealth visits and 85%found the visits to be highly convenient.	Results may not necessarily be generalizable. No demographic data beyond age

CF: Cystic Fibrosis; CG: control group; QoL: Quality of Life; RCADS: Anxiety and Depression Scale in Children-Revised; RCT: Randomized Controlled Study; TR: Telerehabilitation; ys: years

Other researchers have reported positive feedback concerning the feasibility and efficacy of telehealth. Among the respondents to a cross-sectional survey, 77% of adults and 72% of pediatric patients mentioned positive satisfaction with the telehealth experience and 85% of all participants noticed that the visits are incredibly convenient³¹. Phone consultation as a routine clinical practice, for monitoring functional well-being and health status in CF outpatients was acceptable and useful for both patients and healthcare professionals³².

Results from a single-center study showed that the percentage of adult patients with CF using home spirometers increased from 37% in March 2020 to 97% in September 2020. The percentage of patients monitored for spirometry via telemedicine reached 96% by October 2020 compared to 50% in March 2020²⁶. Similar experiences of remote monitoring in CF care programs indicated that over eight months, from October 2020 to May 2021, the number of distributed monitoring equipment (spirometers, weighing scales, and oximeters) for home use increased rapidly from 30% to 70% for spirometers, 50% to 70% for weighing scales and 5% to 10% for oximeters³³.

It is notable that during the pandemic the interest of the researchers was also focused on the monitoring of the healthcare status of pediatric patients. A prospective cross-sectional study was carried out on 144 pediatric CF children (mean age 8.9 years) and their caregivers, from March 11 to December 1, 2020. The hospital's CF team

provided support via video calls and interviewed the participants to collect data on everyday life such as nutritional status, clinical symptoms like anxiety and depression, and medical issues like disease exacerbations. The majority of patients had no remarkable changes in appetite or any other mentioned CF-related symptom. Also, there were no significant issues in the use or supply of CF drugs. However, anxiety was significantly lower in the intervention group than in the control group²⁴.

Telerehabilitation was not widely implemented in patients with CF during the COVID-19 pandemic. A feasibility pilot study investigated the effects of a home-based resistance exercise training program on glucose metabolism, pulmonary function, body composition, and exercise capacity in ten adolescents aged 10 to 18 years with CF and pancreatic insufficiency. The program consisted of 36 whole-body strengthening exercise sessions performed three times per week on nonconsecutive days, with at least 24 hours of recovery between sessions. A set of weight-adjustable dumbbells were given to the patients and a personal trainer supervised the sessions via live video calls using a web-based platform. Trainers provided instructions, exercise demonstrations, and verbal encouragement. Adherence to the program was 78.9%. Virtual personal training induced a significant increase in 2-h C-peptide levels along with a moderate reduction in fasting glucose. The fat-free mass index had a moderate increase whilst the fat percentage had a reduction. Small but statistically significant increases in VO_{2peak} ,

VCO_{2peak}, and ventilation were observed³⁴. Another single-blind randomized trial recruited fourteen CF children aged 6-13 years with their caregivers to follow an exercise program three times a week via Zoom for twelve weeks. During the telerehabilitation sessions, a combination of postural exercises and high-intensity interval training in the form of a game was used. The intervention improved body image and reduced anxiety and depression. Anxiety and depression ratings in caregivers were not significantly affected³⁵ (Table 3b).

Similar effects reported from a psychological support intervention on stress, depression, and anxiety of patients with CF were studied in a group of sixteen participants aged 12–36 years and fourteen parent-caregivers aged 26–49 years, from March to May 2020. The program consisted of four “zoom” sessions lasting 30-40 minutes each, led by a clinical psychologist. Each session focused on self-care, coping skills, mood improvement exercises, and individual emotional challenges. Results demonstrated a significant decrease in stress and depression levels among CF patients and their parents. Anxiety levels remained unchanged³⁶.

Interstitial Lung Diseases

Before the pandemic, digital tools were already being used to deliver healthcare to patients with pulmonary fibrosis. A smartphone app that collected spirometry and pulse oximetry data aided in the monitoring of patients with fibrotic lung conditions³⁷. However, a home monitoring program for 24 weeks in patients with

idiopathic pulmonary fibrosis (IPF) including daily home spirometry, weekly reporting of symptoms and side effects, information about IPF, medication coach, and teleconsultation did not affect overall health-related quality of life (QoL), but it did tend to improve psychological well-being. Although the medication was considerably more frequently adjusted during the study period, satisfaction with medication in terms of efficacy, side effects, and ease of use was comparable in both the intervention and control groups³⁸. Experience from participation in a 10-week virtual pulmonary rehabilitation exercise program delivered for 1-hour sessions, twice weekly, reported improvement of health and well-being of patients with IPF. However, after completing the program, participants could not commit to their participation in physical activity. It is worth noting that a small number of participants reported technical difficulties, but these were easily resolved³⁹ (Table 4).

According to De-las-Heras et al. (2022), a rehabilitation program for patients with sarcoidosis seemed to have no significant beneficial effect on exercise capacity. Fifteen patients versus the control group (n=15) completed a three-month telerehabilitation program that included virtual workouts, videos, and chat consultations with a physiotherapist (Table 4). Each participant was trained for at least 60 minutes per week, creating tailored exercise sets divided into four different intensity categories, combining exercises from a digital database of 250 aerobic and strength 3D exercises. Exercise capacity, as measured by 6MWT distance at three, six, and nine months of follow-up, had

no statistically significant differences between groups. Adherence to the program was 64% with an average of 28 minutes of exercise per session, during the first three months, and participation indicated high levels of satisfaction⁴⁰.

Lung Cancer

Only a few studies have examined the feasibility of telemedicine in patients with lung cancer. In Italy, from June 19 to December 1, 2020, 83 adults with lung cancer participated in video-consulting clinical visits. Patients were prompted to complete an online survey at the end of each virtual meeting recording patients' satisfaction, effectiveness, clarity of communication, project organization, and comparison to an in-person visit. The positive

experience was expressed by 70.59% of all respondents and 76.5% preferred video consulting describing it as preferable to in-person visits⁴¹. Self-monitoring of physical activity using a mobile health app connected with an ankle-worn accelerometer for 24 hours per day for six weeks appeared to be feasible in 41 patients who have undergone gastrointestinal or lung cancer surgery. Patients were able to set their own personal activity goals in the app. Feedback emphasized the ease of use, motivation to be more physically active, and availability of post-discharge support⁴² (Table 4). QoL assessment through a mobile application was also feasible in a small pilot study consisting of 17 middle-aged patients with non-small cell lung cancer⁴³.

TABLE 4. Characteristics of the Selected Studies for patients with Idiopathic Pulmonary Fibrosis, Sarcoidosis, and Lung Cancer							
Authors/year of publication	Purpose	Study population/ sample size/age, ys	Study design	Control group/sample size/ age, ys	Intervention	Reported outcomes	Limitations
O'Shea et al (2022) ³⁹	To explore the experience of a VPR program	IPF/13/69.5(10.4) ys	Qualitative study	no CG	semi-structured interviews (September 2020- April 2022)	High levels of satisfaction and adherence to the program. Ease of accessibility	Low recruitment rate. The program was specifically for people with ILD
Cerdan de las Heras et al (2022) ⁴⁰	To investigate the usefulness and effectiveness of TR on exercise capacity	Sarcoidosis/15/ 51.6±12.7 ys	Single-center, prospective, RCT	Sarcoidosis/15/ 56.1±14.4 ys	Video and chat consultations with a physiotherapist and workout sessions with a VAPA vs the usual standard of care for 3 months (clinicaltrial.gov:NCT03914027)	No significant beneficial effect of TR with VAPA. Exercise capacity at 3, 6, and 9-month follow-ups improved numerically	The low number of participants
Pardolesi et al (2022) ⁴¹	To report the results of a telemedicine program in a cancer center	Lung cancer/ 83/64.0±12 ys	Pilot study	no CG	Video-consulting clinical visits from home using smartphones, tablets, or personal computer (June to December 2020)	A satisfaction score was reported in 70.59% of all the respondents. Most patients (76.5%) preferred video consulting instead of an in-person visit	Difficult to control for selection biases between responders and non-responders. Small sample
de Leeuw et al (2022) ⁴²	To evaluate the feasibility of PA self-monitoring after discharge in patients who have undergone gastrointestinal or lung cancer surgery	gastrointestinal or lung cancer surgery/41/68 (60-73) ys	Feasibility Study	no CG	Ankle-worn accelerometer and the corresponding mobile health app for 6 weeks after surgery (April 2019 to April 2020)	The retention rate was 72%, whereas the rate of missing accelerometer data was 31%. Patients reported a positive experience	The study was conducted in a single hospital setting

CG: control group; ILD: Interstitial Lung Disease; IPF: Idiopathic Pulmonary Fibrosis; PA: Physical Activity; RCT: Randomized Controlled Study; TR: telerehabilitation; VAPA: virtual autonomous physiotherapist agent; VPR: Virtual Pulmonary Rehabilitation; ys: years

Neuromuscular Diseases

In the case of neuromuscular diseases (NMDs), early in the COVID-19 pandemic led to the rapid use of telehealth and remote assessment and focused mainly on respiratory function and respiratory muscle strength assessment as well as on patient-reported outcomes⁴⁴⁻⁴⁶. Remote consultation during the pandemic showed an increased level of satisfaction and willingness to continue with remote respiratory assessment^{47,48}. In most of the studies, e-spirometry was acceptable by patients with Duchenne muscular dystrophy (DMD)^{44,49} and Amyotrophic Lateral Sclerosis (ALS)⁴⁷. All studies noticed benefits such as improving breathing maneuvers and reducing any fear of performing spirometry as a routine assessment process^{44,47}. A limitation was that some patients forgot to take the measurements and declared that sending a reminder about measurements via SMS would be most helpful for implementing the assessments into their daily routines⁵⁰. Moreover, preference was given to the daily

training for respiratory function mainly focused on children (aged between 9-18 years old) with DMD^{45,47,49,51}. Sobierajska et al. (2021)⁵² focused on respiratory exercises such as glossopharyngeal breathing, balloon inflating, and breath stacking, encouraging children to practice at home three times daily. However, low adherence was reported, as more than half of the patients felt overloaded with home-schooling tasks and had not enough trust in healthcare programs conducted indirectly. On contrary, Kenis-Coskun et al. (2022)⁴⁵ comparing the effectiveness of telerehabilitation motor function, functional capacity, and muscle strength in patients with DMD, showed that telerehabilitation is superior to improving muscle strength of the upper and lower limbs than a video home-based exercise program. Additionally, higher compliance was found for the telerehabilitation program compared to video-recorded exercises mainly due to the involvement of their caregivers during the online sessions (Table 5).

TABLE 5. Characteristics of the Selected Studies for patients with Neuromuscular Diseases

Authors/year of publication	Purpose	Study population/sample size/age, ys	Study design	Control group/sample size/age, ys	Intervention	Reported outcomes	Limitations
Sobierajska-Rek et al (2020) ⁴⁹	To establish an online rehabilitation program and motor assessment and to determine the need for TR in DMD	DMD/69 /9.41 (1.5–18) ys	Observational prospective study	No CG	Online motor assessment	Home-based TR can be performed with guidance. Parents and caregivers prefer online videos/instructions/video guidance to live workshops	
Kenis-Coskun et al (2022) ⁴⁵	TR versus home-based video exercises in DMD patients	DMD/19 6-15ys	Single, blind randomized study	DMD	TR and video-exercise groups 30-40min 8wk/3times Feb 2021 -May 2021	TR is superior in improving muscle strength None of the programs improved functional outcomes in ambulatory patients	A limited number of patients Lack of internet connection
Sobierajska-Rek et al (2021) ⁵²	To investigate the feasibility of performing respiratory physical therapy with the use of TR in DMD	DMD /45/11ys	Multi-center observational study	No CG	Online survey Dec2020-Feb 2021	Respiratory TR can be used in DMD and caregivers should be involved	Small sample size
Tattersall et al (2022) ⁴⁸	To evaluate the patient's experiences of performing remote respiratory assessments	ALS/25 /65,2 ys	Observational study	No CG	Remote assessment FVC & PCF Video consultation Sep 2020 - Jan 2021	Remote respiratory assessments and video consultations are useful	Small sample size Selection bias
Hooshmand et al (2021) ⁴⁷	NMDs patients' satisfaction with TH	NMD/50 /15-88 ys	Observational study	No CG	TH satisfaction survey April 2020-June 2020	NMD patients have a favorable view of TH	Small sample size Lack of CG
Wasilewska et al (2021) ⁵¹	To investigate whether it is possible to monitor pulmonary function at home using an individual electronic spirometry system in boys with DMD.	DMD/14 /9-16 ys	Observational prospective study	No CG	E-spirometry (FVC, FEV1, PEF) March 2021 - June 2021	High satisfaction and acceptance of home spirometry Almost 50% of patients were able to perform measurements Need of a reminder about measurements via SMS	Small sample group Short study period Selection bias
Wasilewska et al (2022) ⁴⁴	Influence of e-spirometry monitoring on pulmonary function and respiratory muscles strength	DMD /21 7-22ys	Prospective, control-case, open-label study	No CG	E-spirometry (FVC, FEV1, PEF) MIP/MEP Vignos Scale 6-point Brooke scale Maximal grip strength June 2021- Oct 2021	Improvement in breathing Maintaining the strength of respiratory muscle and handgrip strength.	Small sample group Wide age range

CG: control group; DMD: Duchenne Muscular Dystrophy; FEV1: Forced Expiratory Volume in 1 second; FVC: Forced Vital Capacity;MIP:maximal inspiratory pressure; MEP: maximal expiratory pressure; NMDs: Neuromuscular diseases; PCF: Peak cough flow PR: pulmonary rehabilitation; PEF: Peak Expiratory Flow; TM: telemedicine, TH: Telehealth; TR: Telerehabilitation; ys: years

CONCLUSION

The COVID-19 pandemic urged healthcare transition from face-to-face clinic visits to telemedicine visits. Patients with CRDs acquainted with digital tools, reported a positive experience, potential for self-management monitoring, and adherence to telerehabilitation programs. Virtual education programs were effective for improving patients' knowledge for their CRD. The

increased remote accessibility and the prevention of infection transmission were highlighted as advantages by telehealth supporters. However according to all interventions, the most significant barrier to patient engagement with telehealth was the lack of internet access. As we recover from the pandemic, the implementation of telemedicine in healthcare settings will evolve.

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4: Department of Neurology , Beaumont Hospital Caption List: Table 1: . Published online 2022.

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