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Effect of telemonitoring and telerehabilitation on physical activity, exercise capacity, health-related quality of life and healthcare use in patients with chronic lung diseases or COVID-19: A scoping review

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Abstract

Background: Telemonitoring and telerehabilitation can support home-based pulmonary rehabilitation (PR) and benefit patients with lung diseases or COVID-19. This study aimed to (1) identify which telemonitoring and telerehabilitation interventions (e.g. videoconferencing) are used to provide telehealth care for people with chronic respiratory conditions or COVID-19, and (2) provide an overview of the effects of telemonitoring and telerehabilitation on exercise capacity, physical activity, health-related QoL (HRQoL), and healthcare use in patients with lung diseases or COVID-19.
Methods: A search was performed in the electronic databases of Ovid MEDLINE, EMBASE, and Cinahl through 15 June 2021. Subject heading and keywords were used to reflect the concepts of telemonitoring, telerehabilitation, chronic lung diseases, and COVID-19. Studies that explored the effect of a telerehabilitation and/or telemonitoring intervention, in patients with a chronic lung disease such as asthma, chronic obstructive pulmonary diseases (COPD), or COVID-19, and reported the effect of the intervention in one or more of our outcomes of interest were included. Excluding criteria included evaluation of new technological components, teleconsultation or one-time patient assessment.
Results: This scoping review included 44 publications reporting the effect of telemonitoring (25 studies), telerehabilitation (8 studies) or both (11 studies) on patients with COPD (35 studies), asthma (5 studies), COPD and asthma (1 study), and COVID-19 (2 studies). Patients who received telemonitoring and/or telerehabilitation had improvements in exercise capacity in 9 out of 11 (82%) articles, better HRQoL in 21 out of 25 (84%), and fewer health care use in 3 out of 3 (100%) articles compared to pre-intervention. Compared to controls, no statistically significant differences were found in the intervention groups' exercise capacity in 5 out 6 (83%) articles, physical activity in 3 out of 3 (100%) articles, HRQoL in 21 out of 25 (84%) articles, and healthcare use in 15 out of 20 (75%) articles. The main limitation of the study was the high variability between the characteristics of the studies, such as the number and age of the patients, the outcome measures, the duration of the intervention, the technological components involved, and the additional elements included in the interventions that may influence the generalization of the results.
Conclusion: Telemonitoring and telerehabilitation interventions had a positive effect on patient outcomes and appeared to be as effective as standard care. Therefore, they are promising alternatives to support remote home-based rehabilitation in patients with chronic lung diseases or COVID-19.

Keywords

Telerehabilitation, home telecare, telecare, ehealth, telehealth, telemonitoring, COVID-19, COPD

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Introduction

Chronic lung diseases and COVID-19 are leading causes of disease, death and disability globally[1–4] which entail a substantial burden on the individual[5–7] and healthcare systems.[8,9] Pulmonary rehabilitation (PR) is defined by the "National Heart, Lung, And Blood Institute" as a "supervised program that includes exercise training, health education, and breathing techniques for people who have certain lung conditions or lung problems due to other conditions"[10] is widely recognized as an important treatment for patients suffering from chronic respiratory diseases,[11,12] and has been recommended as a potential beneficial intervention for post-COVID-19 patients.[13] PR has been shown to provide statistically and clinically significant improvements in physical activity, exercise capacity, self-efficacy, and health-related quality of life (HRQoL), and a decrease in healthcare use in patients with lung diseases.[11,14] Despite the multiple benefits identified, it has been estimated that less than 3% of people with chronic lung diseases accessed PR programs[15] which are also hampered by low participation, insufficient attendance, and high dropout rates.[16–19] Home-based PR programs seem to offer a promising alternative[20,21] to overcome well-known PR barriers including, but not limited to, symptom severity, acute exacerbations, transportation, financial difficulties, disruption of daily routines and access to care in remote locations.[17,18,22–25] In addition, the COVID-19 pandemic has highlighted the need for delivering PR programs remotely, safely, and efficiently.[15]

Advances in technology have boosted at-home health service delivery[26,27] and popularized telehealth for those with chronic diseases.[27–30] Telehealth can be described as the use of electronic information and communication technology by professional health care providers to provide and support at-home health care to patients in case of long distances.[31] Evidence indicates that telehealth can enhance healthcare use,[32,33] especially among the populations who cannot otherwise access care.[34] There are several terms used to describe telehealth systems based on their applications. Telerehabilitation is defined as the delivery of rehabilitation services (e.g. assessment, prevention, treatment, education, and counseling) via information and communication technologies.[35] It has been associated with lower healthcare costs compared with traditional inpatient or person-to-person rehabilitation.[36,37] Recent advances in sensor technology have also enabled remote patient telemonitoring, which is the transmission of physiological and other noninvasive data (e.g. heart rate, blood pressure, oxygen saturation, weight, symptoms, etc.) directly to care providers via Bluetooth or digital/broadband/wireless.[36,38] Telemonitoring can be used to recognize and treat changes in the patient's health status as a stand-alone approach (e.g. early detection) or as part of a telerehabilitation intervention. This paper focuses on telemonitoring and telerehabilitation as types of telehealth that can support home-based PR and benefit patients with lung diseases or COVID-19. The purpose of this paper is to depict the use of telemonitoring and telerehabilitation interventions in patients with chronic lung diseases, such as asthma, chronic obstructive pulmonary diseases (COPD), or COVID-19 patients and their association with patient health outcomes. The objectives of this paper were to (1) identify which telemonitoring and telerehabilitation interventions (e.g. videoconferencing) are used to provide telehealth care for people with chronic respiratory conditions or COVID-19, and (2) provide an overview of the effects of telemonitoring and telerehabilitation on exercise capacity, physical activity, HRQoL, and healthcare use in patients with lung diseases or COVID-19.

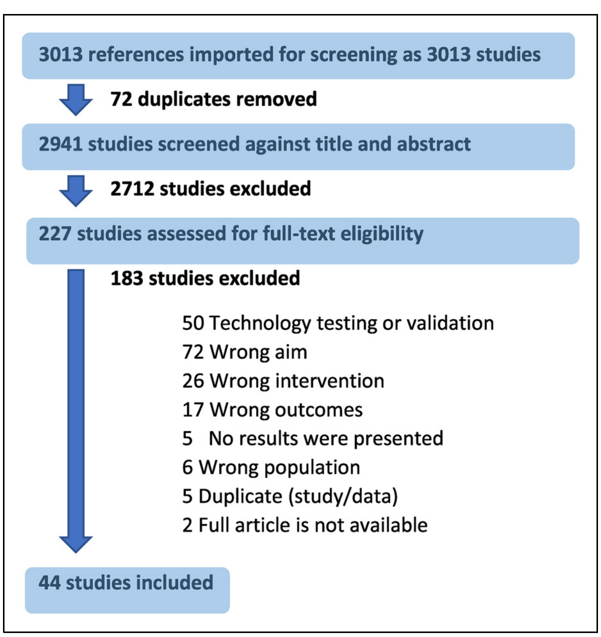

Fig. 1. PRISMA—Literature selection process.

Methods

A health sciences librarian (HL), in consultation with the research team, developed and performed a search in the electronic databases of Ovid MEDLINE, EMBASE, and Cinahl through 15 June 2021. Subject heading and keywords were used to reflect the concepts of telemonitoring, telerehabilitation, chronic lung diseases, and COVID-19 (see supplement 1 for the OVID Medline search). The search was limited to full-text articles published in the English language with full text available. This scoping review of the literature, which has not been registered, was conducted using Preferred Items for Systematic Reviews and Meta-Analysis (PRISMA) (Figure 1). The search retrieved 3013 references. After removing the duplicates, two researchers screened 2941 titles and abstracts and read in full the text of 227 articles. Both researchers reviewed independently the articles and selected 44 publications that met the inclusion criteria of (1) the study explored the effect of a telerehabilitation and/or telemonitoring intervention, (2) in patients with a chronic lung diseases, such as asthma, COPD, or COVID-19 patients, (3) and reported the effect of the intervention in one or more of the following outcomes: exercise capacity, physical activity, HRQoL, or healthcare use. The main reasons for exclusion of the studies included: (1) the study aimed to validate a new technological component instead of evaluating an intervention, (2) the intervention was only teleconsultation or one-time assessment, or the effect of the intervention in one of the (3) populations or (4) outcomes of interest were not reported.

Data extraction and synthesis

Information from the 44 articles was summarized in Table 1, which presented: (1) author(s)' name, (2) country of the study, (3) type of study, (4) intervention group and control group, (5) technology used in the study, (6) duration of the intervention, (7) participants' condition, and (8) description of the study population. The effect of telemonitoring and telerehabilitation on physical activity, exercise capacity, health-related quality of life and healthcare use in patients with chronic lung diseases or COVID-19 was extracted and compiled in Tables 2–4.

Results

All 44 manuscripts were original research published between 2005 and 2021. The studies were conducted in Australia (5), Canada (5), USA (5), Denmark (4), Italy (4), Spain (4), UK (4), China (3), the Netherlands (3), Ireland (2), New Zeeland (1), Norway (1), Russia (1), Sweden (1), and 1 study in Austria, Germany, and Switzerland. The main characteristics of the included studies are presented in Table 1. Twenty-eight manuscripts reported on randomized controlled studies, 11 pre-post intervention studies, 2 matched population studies, 1 controlled non-randomized study, 1 quasi-randomized clinical trial, and 1 cohort study. Follow-up periods reported range between 10 days and 36 months. The number of participants involved in intervention groups of the studies ranged between 8 and 619 (median: 45). Thirty-five of the studies were conducted in patients with COPD, 5 in patients with asthma, 1 included patients with COPD and/or asthma, and 2 in patients with COVID-19. Two studies were conducted on children and the rest on adult patients (Table 1).

Interventions and technology

Table 1 describes the details of the interventions and the technology used. The effect of telemonitoring (25 studies), telerehabilitation (8 studies) or both interventions combined (11 studies) were reported on the physical activity, exercise capacity, HRQoL and healthcare use of patients with respiratory diseases or COVID-19. These technology-enabled remote interventions were implemented as a stand-alone approach or in combination with other elements (e.g. standard care). Twenty-seven of the studies involved mobile apps, web pages, or virtual platforms accessed using a laptop, tablet or smartphone.[39,41–44,46,47,49,55,59–61,63–69,71,72,74–76,79–81] In two studies the intervention was delivered using a teleconference platform,[66,76] and one social platform.[67] Other transmitting devices/systems used in the studies included the health buddy device,[40,51] the iRobi robot,[73] a PalmOne,[45] touch screen telemonitoring equipment,[57] a home health system connected to a phone line,[53] a computer-linked interactive phone tele-system,[48] a tele-modem,[50,54,62,82] a satellite platform,[83] computer or push-bottom telephone,[58] handheld monitor connected to a phone line,[52] a digital pen and health dairy paper together with SMS.[56] Portable devices used to monitor patients' remotely included pulse oximeters (oxygen saturation and heart rate), spirometers (lung function), and accelerometers (physical activity) among others. Sixteen studies used more than one device to collect patient data. Information from the monitoring devices was collected using Bluetooth technology, manually entered, or verbally reported by participants to the research team or healthcare providers.

Exercise capacity and physical activity

A significant improvement in exercise capacity was reported in COVID-19 patients who received home-based telerehabilitation[64] (Table 2). Increased baseline exercise capacity was also found in COPD patients who received telemonitoring,[51] telerehabilitation (3 of 4 studies),[66,69,70] or a combination of both.[76–78,81] However, only one study that explored the effect of telemonitoring[51] and another that combined telemonitoring and telerehabilitation[81] found greater improvement in exercise capacity in intervention groups compared to controls. Telerehabilitation[76–78,81] alone or in combination with telemonitoring was not associated with changes in physical activity compared to control groups among COPD patients.[66,71,81]

HRQoL and/or health status

Overall well-being improved in 83% of COVID-19 patients who participated in an intervention involving telerehabilitation and telemonitoring[75] (Table 3). Telemonitoring interventions were associated with an improvement in HRQoL in patients with asthma[42,45,58,61,63] and COPD (4 of 6 studies),[46,49,51,60] and no changes in HRQoL were identified in one study that included both asthma and COPD patients combined.[44] Nevertheless, when compared to

Table 1. Main characteristics of the studies included.

Author Year Country	Type of study	Intervention Group (IG) Control Group (CG)	Technology	>1 Monitoring devices involved (Yes/no)	Duration of the intervention	Disease	Intervention group: Number of participants	Intervention group: Age mean years (SD)	Intervention group: Males N (%)	Control group: Number of participants	Control group: Age Mean years (SD)	Control group: Males N (%)
Telemonitoring												
Antoniades, Nick 2012[39] Australia	RCT	IG: Remote In-home monitoring (TeleMedCare) + standard best practice. CG: Standard best practice	Laptop (software), daily monitoring spirometry, vital functions, oximetry, etc.	Yes	12 Months	COPD	22	70 (10)	10 (83)	22	68 (9)	10 (83)
Au, David 2015[40] USA	Matched group design (1:1)	IG: Telehealth system combined with care management program (Health Buddy Program) CG: Matched to similar baseline characteristics	Four button Health Buddy device; asks for vital signs, disease symptoms, provides feedback, and categorizes patient's medical risk.	No	3 Years	COPD	619	75 (8)	338 (55)	619	74 (10)	338 (55)
Boer, Lonneke 2019[41] Netherlands	RCT	IG: Smart mobile health tool for self-management (mHealth tool). CG: Paper action plan	Mobile phone (app), collected information on symptom changes and physiological measurements using a pulse oximeter, spirometer, and forehead thermometer.	Yes	12 Months	COPD	43	69 (8)	25 (58)	44	65 (8)	29 (66)
Chan, Debora 2007[42] USA	RCT	IG: Internet-based home monitoring and education. CG: Office-based care	Home computer (website), camera and internet access. Digital video camera to capture patient's performance.	No	52 Weeks	Asthma	60	10 (3)	38 (63)	60	9 (3)	37 (62)
Chau, Janita 2012[43] Hong Kong	RCT	IG: Telecare service (ASTRI) + nurse home visit (education) CG: Only nurse home visit (education)	Mobile phone, respiratory rate sensor, pulse oximeter. Internet and wireless systems, databases and software for critical decision analysis, and support.	Yes	2 Months	COPD	22	73 (6)	21 (95)	22	72 (6)	18 (82)
Cushen, Brenda 2021[44] Ireland	Pre-post	GI: Community virtual ward model (patient information transferred to hospital portal)	Bluetooth-enabled smartphone and hospital portal. Remote monitoring of daily oxygen saturations, heart rate, and spirometry measurements.	Yes	Mean 10 (4) days admission to discharge	COPD and/or asthma	20	64 (13)	7 (35)	N/A	N/A	N/A

(continued)

Table 1. Continued.

Author Year Country	Type of study	Intervention Group (IG) Control Group (CG)	Technology	>1 Monitoring devices involved (Yes/no)	Duration of the intervention	Disease	Intervention group			Control group		
							Number of participants	Age mean years (SD)	Males N (%)	Number of participants	Age Mean years (SD)	Males N (%)
de Jongste, Johan 2009[45] Netherlands	RCT	GI: Daily telemonitoring of exhaled nitric oxide + monitoring symptoms CG: Symptoms monitoring only	PalmOne, airway inflammation monitor (NIOX MINO; Aerocrine, Solna, Sweden) that measures FENO0.05	No	30 Weeks	Asthma	77	11 (2)	46 (60)	74	11 (4)	54 (73)
Deng, Ning 2020[46] China	Pre-post	GI: Mobile health technology to deliver a community-based closed-loop management system (app)	MHealth system: smartphone (patient app), workstation (doctor), a cloud server, and a simple peak flow meter.	No	6 Months	COPD	39	61 (6)	36 (92)	N/A	N/A	N/A
Ding, Hang 2014[47] Australia	Pre-post	GI: A mobile-phone-based home monitoring system (app)	Mobile phone to record COPD symptoms and vital signs on portal. Thermometer, pulse oximeter.	Yes	6 Months	COPD	10	65 (9)	5 (50)	N/A	N/A	N/A
Farias, Raquel 2019[48] Canada	Pre-post	GI: Phone interactive telesystem (computer-linked interactive phone telesystem)	Card (PIN) and the Telesystem contact information with automated phone call questions and a callback notification.	No	12 Months	COPD	256	70 (9)	117 (46)	N/A	N/A	N/A
Farmer, Andrew 2017[49] UK	RCT	GI: Digital health system (EDGE, Self-management, anD support prorGrammE). CG: Standard care	EDGE platform, tablet, and Bluetooth-enabled oximeter.	No	12 Months	COPD	110	69 (9)	68 (62)	56	69 (10)	34 (61)
Jódar-Sánchez, Francisco 2013[50] Spain	RCT	IG: Home telehealth program (Tele-Modem, Aerotel Medical Systems) CG: Usual care.	Spirometer, a pulse oximeter, heart rate, blood pressure monitor (model UA-767 BT, A&D Company). Data sent via a hub (Tele-Modem, Aerotel Medical Systems) connected to the patient's home telephone line.	Yes	4 Months	COPD	24	74 (8)	23 (96)	21	71 (10)	20 (95)
Koff, Patricia 2021[51] USA	Quasi-randomized clinical trial	IG: Proactive iCare (healthcare delivery model that couples integrated care with remote monitoring) CG: Usual care	Health buddy, finger pulse oximeter, handheld spirometer and pedometer.	Yes	9 Months	COPD	352	68 (8)	205 (58)	159	68 (9)	106 (67)

(continued)

Table 1. Continued.

Author Year Country	Type of study	Intervention Group (IG) Control Group (CG)	Technology	>1 Monitoring devices involved (Yes/no)	Duration of the intervention	Disease	Intervention group			Control group		
							Number of participants	Age mean years (SD)	Males N (%)	Number of participants	Age Mean years (SD)	Males N (%)
Lewis, Keir E 2010[52] UK	RCT	IG: Home telemonitoring (telemonitoring via the home telephone line) + standard care CG: Standard care	Handheld telemonitor connected via telephone line, thermometer, and pulse oximeter probe connected to the monitor.	Yes	6 Months	COPD	20	70 (range 61–73)	10 (50)	20	73 (range 63–79)	10 (50)
McDowell, Janet 2015[53] Ireland	RCT	IG: Home-based healthcare with telemonitoring (telecommunications device connected directly to patient's phone line) CG: Usual care	Home telehealth system (HomMed, Honeywell, USA) self-monitoring to record vital signs (finger probe and blood cuff) and answer questions.	Yes	6 Months	COPD	55	69 (7)	32 (58)	55	70 (7)	30 (54)
Pare, Guy 2013[54] Canada	RCT	IG: Home telemonitoring (touchscreen, modem) CG: Regular home care visits.	Touch screen with an integrated modem (TELUSTM) to send clinical data.	No	21.5 Months	COPD	60	67 (6)	19 (32)	60	68 (6)	19 (32)
Pedone, Claudio 2013[55] Italy	RCT	IG: Multiparametric telemonitoring of vital signs CG: Standard care	Cellular telephone coupled with wristband containing Bluetooth sensors (heart rate, physical activity, body temperature, and a pulse-oximeter).	No	9 Months	COPD	50	74 (6)	36 (72)	49	75 (6)	31 (63)
Persson, Hans 2020[56] Sweden	Cohort study	IG: Health Diary Telemonitoring and Hospital-Based Home Care (HBCH).	Digital pen and a Health Diary paper form to report daily health status.	No	12 Months	COPD	36	75 (6)	14 (39)	NA	NA	NA
Pinnock, Hilary 2013[57] UK	RCT	IG: Touch screen telemonitoring equipment + clinical care. CG: Clinical care.	Touchscreen Telemonitoring equipment to record and transmit daily questionnaires and monitor oxygen. Algorithms alerts.	No	12 Months	COPD	128	69 (8)	53 (41)	128	68 (8)	63 (49)

(continued)

Table 1. Continued.

Author Year Country	Type of study	Intervention Group (IG) Control Group (CG)	Technology	>1 Monitoring devices involved (Yes/no)	Duration of the intervention	Disease	Intervention group: Number of participants	Intervention group: Age mean years (SD)	Intervention group: Males N (%)	Control group: Number of participants	Control group: Age Mean years (SD)	Control group: Males N (%)
Rasmussen, Linda 2005[58] Denmark	RCT (3 groups)	IG: Internet-based monitoring asthma tool. CG1: Asthma specialist treatment CG2: General practitioner treatment	Internet diary or push-button phone. Peak flowmeter (Vitalograph, Ltd, Maid Moriton, Buckingham, United Kingdom).	No	6 Months	Asthma	85	28 (range 14–44)	27 (32)	CG1: 88 CG2:80	CG1: 30 (range 19–45) CG2:30 (range 20–45)	CG1: 30 (34) CG2: 30 (38)
Schou, Lone 2013[59] Denmark	RCT	GI: telemedicine-based treatment (videoconferencing system-daily ward rounds) CG: conventional hospital admission	Touch screen PC and additional devices (pulse oximeter, spirometer, and thermometer) for monitoring the vital signs.	No	3 Months	COPD	22	68 (12)	10 (45)	22	73 (10)	8 (36)
Stamenova, Vess 2020[60] Canada	RCT (3 arms)	IG: Technology -Enabled remote monitoring program. CG1: Technology-Enabled Self-Management (web-based) CG2: Standard care	Web-based portal and Bluetooth devices: custom tablet computer pulse wave wrist cuff monitor, oximeter, weighing scale, and thermometer.	Yes	6 Months	COPD	41	71 (9)	23 (56)	CG1: 41 CG: 40	CG1: 71 (7) CG2: 72 (9)	CG1: 23 (56) CG2: 21 (52)
van Gaalen, Johanna 2013[61] Netherlands	RCT (multicenter nonblinded, pragmatic randomized controlled parallel trial)	IG: Internet-based self-management support. CG: Usual care.	Website platform. Handheld spirometer and reporting symptom score.	No	30 Months	Asthma	47	36 (8)	12 (26)	60	37 (8)	19 (32)
Vianello, Andrea 2016[62] Italy	RCT	IG: Home telemonitoring (Gateway device for data transmission over telephone) CG: Usual care	TM system: finger pulse-oximeter and a gateway device for data transmission over a telephone line to a central data management unit located at the Veneto Regional e-Health Centre.	No	12 Months	COPD	230	75 (6)	164 (71)	104	76 (6)	76 (73)
Zairina, Elida 2015[63] Australia	RCT	IG: Telehealth program CG: Usual care	Mobile application Breathe-easy© supported by a Bluetooth-enabled handheld device (COPD-6 R), which was used for self-monitoring of lung function.	No	6 Months	Asthma	36	31 (4)	0	36	31 (4)	0

(continued)

Table 1. Continued.

Author Year Country	Type of study	Intervention Group (IG) Control Group (CG)	Technology	>1 Monitoring devices involved (Yes/no)	Duration of the intervention	Disease	Intervention group: Number of participants	Intervention group: Age mean years (SD)	Intervention group: Males N (%)	Control group: Number of participants	Control group: Age Mean years (SD)	Control group: Males N (%)
Telerehabilitation												
Bermejo-Gil, Beatriz 2021[64] Spain	Pre-post	IG: Home-based telerehabilitation system (RespiraCon Nosotros)	Web application for respiratory exercises and chat function for interaction compatible with computer, tablet, television, and mobile.	No	1 Month	COVID-19	15	range 28–38	8 (53)	NA	NA	NA
Burkow, Tatjana 2015[65] Norway	Pre-post	IG: PR in home-based online groups (videoconference)	Internet-based comprehensive, multidisciplinary pulmonary rehabilitation program + step counter.	No	9 Weeks	COPD	10	61 (range 46–72)	5 (50)	N/A	N/A	N/A
Hansen, Henrik 2020[66] Denmark	RCT	IG: Pulmonary Telerehabilitation program (videoconference). CG: Conventional PR program	Videoconference software system installed on a single touch screen.	No	10 Weeks	COPD	67	68 (8)	32 (48)	67	68 (9)	28 (42)
Yuyu 2020[67] China	RCT	IG: Pulmonary internet explorer Rehabilitation (PeR) program based on social media (WeChat) CG: Face-to-face PR rehabilitation	PeR includes two ports: the computer end and the WeChat end.	No	3 Months	COPD	53	70 (6)	44 (83)	53	71 (7)	43 (81)
Jiménez-Reguera, Begoña 2020[68] Spain	RCT	IG: mHealth Web-Based platform (HappyAir) CG: Hospital scheduled evaluations.	HappyAir app: educational program and data collection related to physical activity and disease, recording medication intake, daily exercise time (minutes), level of tiredness and daily mood.	No	12 Months	COPD	20	68 (6)	9 (41)	24	68 (7)	13 (59)
Lewis, Adam 2021[69] UK	pre-post	IG: Online platform delivery of PR	E-learn Moodle platform (videoconference, messaging)	No	6 Weeks	COPD	17	69 (10)	8 (47)	NA	NA	NA
Stickland, Michael 2011[70] Canada	RCT	IG: PR delivered via Telehealth CG: PR delivered in person (standard outpatient hospital-based program)	Videoconference	No	8 Weeks	COPD	147	69 (8)	78 (53)	262	69 (9)	125 (44)

(continued)

Table 1. Continued.

Author Year Country	Type of study	Intervention Group (IG) Control Group (CG)	Technology	>1 Monitoring devices involved (Yes/no)	Duration of the intervention	Disease	Intervention group			Control group		
							Number of participants	Age mean years (SD)	Males N (%)	Number of participants	Age Mean years (SD)	Males N (%)
Telemonitoring and telerehabilitation												
Benzo, Roberto 2021[71] USA	RCT	IG: Home-based program with video-guided exercises (website) + phone call health coaching* CG: Waiting list 8 weeks and the intervention was offered afterwards	Computer tablet: video-guided exercises using an oximeter, an activity monitor and daily self-report of symptoms.	Yes	8 Weeks	COPD	72	69 (8)	34 (47)	74	68 (9)	37 (50)
Bhatt, Surya 2019[72] USA	Matched group design (1:2)	IG: Telehealth PR (video conference) * CG: Contemporaneous subjects who had been hospitalized for a COPD exacerbation but did not receive the intervention	Smartphone with video capabilities to facilitate two-way live videoconferencing. Automatic sphygmomanometers (blood pressure), and a pulse oximeter (heart rate and oxygen saturation).	Yes	12 Weeks	COPD	80	64 (10)	49 (61)	160	63 (11)	92 (57)
Broadbent, Elizabeth 2018[73] New Zealand	RCT	IG: iRobi robot (monitor health and prompt medical contact) CG: Standard care	Robot with Wi-Fi linked smart inhalers: (1) Measure pulse oximetry, forced expiration volume, heart rate, and symptoms, mental state, and functional status using the Clinical COPD Questionnaire (2) reminding medication and inhalers and record their adherence several times a day; (3) remind rehabilitation exercises (4) provide education about COPD; (5) I am feeling unwell function (6) trends over time health status and adherence.	No	4 Months	COPD	30	70 (10)	11 (37)	30	69 (9)	12 (40)

(continued)

Table 1. Continued.

Author Year Country	Type of study	Intervention Group (IG) Control Group (CG)	Technology	>1 Monitoring devices involved (Yes/no)	Duration of the intervention	Disease	Intervention group: Number of participants	Intervention group: Age mean years (SD)	Intervention group: Males N (%)	Control group: Number of participants	Control group: Age Mean years (SD)	Control group: Males N (%)
Galdiz, Juan 2021[74] Spain	RCT	IG: Pulmonary Telerehabilitation program (web-based platform) CG: Standard care	Web-based platform, and a telerehabilitation kit (mobile phone, pulse oximeter, dumbbells and exercise bicycle).	No	12 Months	COPD	46	62 (8)	30 (65)	48	63 (6)	33 (68)
Gilmutdinova, Ilmira R 2021[75] Russia	pre-post	IG: Telemedicine platform (COVIDREHAB)	A mobile phone, tablet or computer, an Internet connection and an e-mail address on this device. Platform: information and analytical system for remote monitoring of medical rehabilitation.	No	2 Weeks	COVID-19	178	50 (range 32–82)	70 (39)	NA	NA	NA
Holland, Anne 2013[76] Australia	Pre-post	IG: Telerehabilitation (video collaborative software)	A tablet computer was used for videoconferencing. A pulse oximeter (oxyhemoglobin saturation and heart rate).	No	8 Weeks	COPD	8	66 (range 56–83)	3 (38%)	NA	NA	NA
Marquis, Nicole 2015[77] Canada	Pre-post	IG: In-home PR (video conferencing system)	Videoconferencing system, internet connection with encrypted transmission. Wireless oximeter (oxygen saturation and heart rate).	Yes	6 Months	COPD	23	65 (7.1)	8 (35)	NA	NA	NA
Paneroni, Mara 2015[78] Italy	controlled, non-randomized pilot study	IG: Telerehabilitation (satellite platform) CG: Standard outpatient rehabilitation program	Home telemonitoring platform, medical devices (oximeter, steps counter)	Yes	40 Days	COPD	18	6 5(10)	16 (89)	18	66 (6)	15 (83)
Rassouli, Frank 2018[79] Switzerland, Austria, and Germany	Observational (pre-post)	IG: Digital multidisciplinary PR (App)	Multiplatform smartphone application with exercise videos. Pedometer.	No	20 Days	COPD	34	59 (8)	8 (24)	NA	NA	NA
Ringbaek, Thomas 2015[80] Denmark	RCT	IG: Telehealth care (telemonitoring equipment) with the option of video consultation CG: Usual care	Tablet computer with a web camera, a microphone, and measurement equipment (spirometer, pulse oximeter, and bathroom scale).	Yes	6 Months	COPD	141	69 (9)	55 (39)	140	69 (10)	76 (54)

(continued)

Table 2. Effect of telemonitoring and/or telerehabilitation on physical activity and exercise capacity in patients with lung diseases or COVID-19.

			Exercise capacity			Physical activity		
	Disease	Study	IG change from pre-intervention	IG effect in comparison with CG	Instrument/tool used to assess the outcome	IG change from baseline	IG effect in comparison with CG	Instrument/tool used to assess the outcome
Telemonitoring	COPD	Koff, P. 2021[51]	↑	↑	6MWT			
Telerehabilitation	COVID-19	Bermejo-Gil, B. 2021[64]	↑	NA	Borg scale			
	COPD	Hansen, Henrik 2020[66]	↑	=	6MWT, 30 s sit-to stand test	no	=	Triaxial accelerometer
		Stickland, M. 2011[70]	↑	=	12 min walk test			
		Lewis, A. 2021[69]	↑	NA	1 min sit-to stand test			
		Jiménez-Reguera, B. 2020[68]	no	=	6MWT			
Telerehabilitation and telemonitoring	COPD	Benzo, R. 2021[71]				NR	=	ActiGraph
		Tsai, L. 2017[81]	↑	↑	Endurance shuttle walk test	no	=	Triaxial accelerometer
			↑	=	6MWT			
		Paneroni, M. 2015[78]	↑	=	6MWT			
		Holland, A. 2013[76]	↑	NA	6MWT			
		Marquis, N. 2015[77]	↑	NA	6MWT			
		Galdiz, J. 2020[74]	no	=	6MWT			

IG: Intervention group; CG: control group; 6MWT: 6-min walking test NA: not applicable. ↑: significantly better outcome; =: no significant difference in outcome change between groups. not reported. NR: data and/or significance level not reported.

Table 3. Effect of telemonitoring and/or telerehabilitation on health-related quality of life and/or health status in patients with lung diseases or COVID-19.

			Health-related quality of life (HRQoL) and/or health status		
	Disease	Study	IG change from pre-intervention	IG effect in comparison with CG	Instrument/tool used to assess the outcome
Telemonitoring	Asthma	Rasmussen, L. 2005[58]	↑	↑ (than the 2 CGs)	Asthma-related quality of life (AQLQ)
		van Gaalen, J. 2013[61]	↑	↑	AQLQ
		Zairina, E. 2015[63]	↑	↑	mAQLQ (mini asthma quality of life questionnaire)
		de Jongste, J. 2009[45]	↑	=	Pediatric asthma caregiver quality of life questionnaire (PACQLQ)
		Chan, D. 2007[42]	↑	NR	Pediatric asthma quality of life questionnaires (PAQLQ) applied to caregiver
	COPD and/or asthma	Cushen, B. 2021[44]	no	NA	EQ-VAS questionnaire
	COPD	Koff, P. 2021[51]	↑	↑	SGRQ
		Farmer, A. 2017[49]	↑	↑	EQ-5D-5L questionnaire
			↑	=	SGRQ
		Stamenova, V. 2020[60]	↑	= (in the 3 groups)	SGRQ
		Deng, N. 2020[46]	↑	NA	COPD assessment test (CAT)
		Antoniades, N. 2012[39]	no	=	Chronic respiratory disease questionnaire (CRDQ), 36-Item short from survey (SF-36)
		Persson, H. 2020[56]	no	NA	SGRQ
		McDowell, J. 2015[53]	NR	↑	SGRQ
				=	EQ-5D questionnaire
		Boer, L. 2019[41]	NR	=	EQ-5D questionnaire, Nijmegen clinical screening instrument (NSCI), Clinical COPD Questionnaire (CCQ)
		Chau, J. 2012[43]	NR	=	Chronic respiratory questionnaire (CRQ)
		Jódar-Sánchez, F. 2013[50]	NR	=	SGRQ, EuroQoL-5D questionnaire
		Lewis, K. 2010[69]	NR	=	SGRQ, and EuroQoL EQ-5D questionnaire
		Pinnock, H. 2013[57]	NR	=	SGRQ
		Schou, L. 2013[59]	NR	=	SGRQ
		Vianello, A. 2016[62]	NR	=	SF-36
Telerehabilitation	COPD	Stickland, M. 2011[70]	↑	=	SGRQ
		Burkow, T. 2015[65]	↑	NA	SGRQ
		Lewis, A. 2021[69]	↑	NA	CRQ
		Rassouli, F. 2018[79]	↑	NA	CAT, CRQ
		Jiang, Y. 2020[67]	↑	=	CAT, SGRQ
		Jiménez-Reguera, B. 2020[68]	↑	=	SGRQ
			no	=	CAT, EuroQOL-5D questionnaire
		Hansen, H. 2020[66]	↑	=	

(continued)

Table 3. Continued.

			Health-related quality of life (HRQoL) and/or health status		
	Disease	Study	IG change from pre-intervention	IG effect in comparison with CG	Instrument/tool used to assess the outcome
					Clinical COPD Questionnaire (CCQ)
			no	=	EQ-5D-VAS
Telerehabilitation and telemonitoring	COVID-19	Gilmutdinova, I. 2021[75]	↑	NA	Survey (Overall well-being improved in 83% of the participants)
	COPD	Holland, A. 2013[76]	↑	NA	CRQ
		Marquis, N. 2015[77]	↑	NA	CRQ
		Paneroni, M. 2015[78]	↑	=	SGRQ
		Tsai, L. 2017[81]	↑	=	CAT
			no	=	CRDQ (Chronic respiratory disease Questionnaire)
		Benzo, R. 2021[71]	NR	=	CRQ
		Broadbent, E. 2018[73]	NR	=	CCQ
		Galdiz, J. 2020[74]	no	=	SF-36, Chronic respiratory disease Questionnaire (CRQ)

IG: Intervention group; CG: control group. NA: not applicable. EQ-VAS: EuroQol-visual analogue scales; CAT: COPD assessment test; SGRQ: St George's Respiratory Questionnaire; CRQ: chronic respiratory disease questionnaire; ↑: significantly better outcome; =: no significant difference in outcome change between groups. NR: data and/or significance level not reported.

control groups, telemonitoring was associated with a greater improvement in HRQoL only in 75% (3 of 4) of studies in asthma patients[46,49,51,58,60,61,63] and in 23% (3 of 13) of studies in COPD patients.[49,51,53] Telerehabilitation[65–70,79] alone and the combination of telerehabilitation with telemonitoring[76–78,81] were associated with improvement in HRQoL in COPD patients. However, no significant difference in HRQoL change was found between the intervention groups and controls.[66–68,70,71,73,74,78,81]

Healthcare use

A decrease in pre-intervention hospital admissions, length of hospitalization, and visits to the emergency department and GP's office were reported in COPD patients who participated in telemonitoring interventions.[47,48,51] Furthermore, 6 out of 13 studies reported fewer urgent visits to GP's office,[51] fewer visits to the pulmonary specialist[62] and nurse practitioner,[49] fewer hospital admissions,[40,55] and readmissions,[62] fewer days of hospitalization, and fewer ER visits[54] in patients with COPD who received telemonitoring compared to control groups. However, 7 of 13 studies found no significant difference in health care use between controls and patients with COPD,[39,41,43,50,53,57,60] who participate in telemonitoring interventions, and the same was reported in two studies among patients with asthma.[42,63] No significant differences were found in COPD exacerbation-related hospital admission or in all causes of hospitalization between COPD participants of a telerehabilitation program compared with a conventional pulmonary rehabilitation (PR) program.[66] Three of 4 studies reported lower use of healthcare in COPD patients who participated in interventions combining telerehabilitation and telemonitoring compared with control groups.[72,80,82]

Discussion

This paper aimed at portraying the use of telemonitoring and telerehabilitation in patients with chronic lung diseases such as asthma, COPD or COVID-19 patients and the effects of these modalities of intervention on physical activity, exercise capacity, health-related quality of life and healthcare use. A scoping review methodology was followed to explore the literature in the field. 27.3% of the studies retrieved were published after 2020 demonstrating the expanding need for technology in PR, especially after the rise of COVID-19. The first objective was to identify the telemonitoring and telerehabilitation interventions that are used to provide telehealth care for people with chronic respiratory conditions or

Table 4. Effect of telemonitoring and/or telerehabilitation on healthcare use in patients with lung diseases.

	Disease	Study	Healthcare use: IG change from pre-intervention	Healthcare use: IG effect in comparison with CG	Healthcare use: Instrument/tool used to assess the outcome
Telemonitoring	Asthma	Chan, D. 2007[42]	NR	=	Number of ED visits, hospitalizations, unscheduled asthma-related visits.
		Zairina, E. 2015[63]	NR	=	Number of unscheduled health-care visits.
	COPD	Koff, P. 2021[51]	↓	↓	COPD-related urgent office GP visits (decreased only on IG).
			↓	=	COPD-related hospitalizations, hospital LOS, ED visits, ICU hospitalization.
			no	=	Non-COPD urgent office GP visits, hospitalizations, hospital LOS, ED visits, ICU hospitalizations.
		Ding, H. 2014[47]	↓	NA	Hospital admissions, ED presentations, and GP visits.
		Farias, R. 2019[48]	↓	NA	Respiratory-related ER visits, and COPD-related hospitalizations.
		Au, D. 2015[40]	NR	↓	Quarterly all-cause hospital admissions, respiratory-related hospital admissions.
		Pare, G. 2013[54]	NR	↓	Number of hospitalization days and visits to ER.
		Pedone, C. 2013[55]	NR	↓	COPD-related hospitalizations.
		Farmer, A. 2017[49]	NR	↓	Visits to the GP practice nurses.
			NR	=	Relative risk of hospital admission.
		Vianello, A. 2016[62]	NR	↓	Readmission rate AECOPD and/or for any cause, appointment with a pulmonary specialist.
			NR	=	Hospitalization rate for AECOPD (acute exacerbations of COPD) and/or for any cause.
		Antoniades, N. 2012[39]	NR	=	Number of COPD-admission/year, COPD-related length of stay (LOS) days/year, total admission/year, total LOS days/year.
		Boer, L. 2019[41]	NR	=	Exacerbation-related hospital admissions, unscheduled respiratory-related healthcare consultations.
		Chau, J. 2012[43]	NR	=	Number of emergency department visits and hospital re-admissions.
		Jódar- Sánchez, F. 2013[50]	NR	=	ED visits, specialized consultations, hospitalizations.
		McDowell, J. 2015[53]	NR	=	Number of ED visits, hospitalizations, or contacts with GP.
		Pinnock, H. 2013[57]	NR	=	Hospital admissions due to COPD or all cause, duration of hospital admission.
		Stamenova, V. 2020[60]	NR	=	Hospitalizations, ED visits, or clinic visits.
Telerehabilitation	COPD	Hansen, H. 2020[66]	NR	=	Hospital admission related to COPD exacerbations; all causes of hospitalization.
Telerehabilitation and Telemonitoring	COPD	Bhatt, S. 2019[72]	NR	↓	30-day all-cause readmission and

(continued)

Table 4. Continued.

Disease	Study	Healthcare use: IG change from pre-intervention	IG effect in comparison with CG	Instrument/tool used to assess the outcome
				AECOPD (acute exacerbation of COPD) readmission.
	Vitacca, M. 2009[82]	NR	↓	Hospitalizations, ER admissions and urgent GP calls.
	Ringbaek, T. 2015[80]	NR NR	↓	Visits to the respiratory outpatient clinic.
			=	Number of hospital admissions (for COPD or all causes), time to first admission, length of stay, visit to ER.
	Broadbent, E. 2018[73]	NR	=	Hospitalizations for respiratory problems, total number of days in hospital for respiratory problems.

IG: Intervention group; CG: control group. ED: emergency department; ER: emergency room; GP: general practitioner; ↓ significantly lower; = no significant difference between groups. NA: not applicable. NR: data and/or significance level not reported.

COVID-19. The literature review identified various technologies and technology-based approaches used to provide telemonitoring and/or telerehabilitation interventions for patients with asthma, COPD, or COVID-19. The technologies used were classified into two types. The first type included portable and mobile technologies to capture physiological and other-non-invasive variables measured by patients themselves at home (e.g. heart rate, oxygen saturation) and the second type included information and communication technologies that allow seamless transfer of health data from the remote location to the healthcare provider. Overall, technologies were diverse, involved various levels of complexity, and were deployed in specific ways depending on the cases used. As such, we have classified the interventions into telemonitoring where only the surveillance of physiological and other non-invasive variables was needed, telerehabilitation where a PR or exercise intervention was administered remotely, or a combination of both.

The second objective of this paper was to provide an overview of the effects of telemonitoring and telerehabilitation on exercise capacity, physical activity, HRQoL, and healthcare use in patients with lung diseases or COVID-19. Results indicated that telemonitoring and telerehabilitation were associated with an improvement in exercise capacity, higher HRQoL, and lower healthcare use in these patients. Furthermore, these interventions produced outcomes comparable to standard care, which aligns with previous evidence that reported similar benefits of telerehabilitation to traditional in-person outpatient PR programs.[84,85] Previous evidence has also suggested that telemonitoring interventions can contribute to better disease management, higher patient empowerment, higher patient engagement and satisfaction, facilitate communication between the patient and healthcare team, and facilitate data collection and data access in patients with COPD.[86] Some potential barriers associated with these interventions included heterogeneity of care, lack of patient comfort with technology, patient resistance, time-consuming, increased workload for healthcare providers and staff shortages.[86] From the cost-effective perspective, evidence suggested that although technology-based interventions require an initial financial investment, they will substantially reduce costs in the long-term, potentially due to a reduction in healthcare use and travel costs.[87]

Overall, evidence suggested that telemonitoring and telerehabilitation are potentially valuable mechanisms to improve patient care and access, especially in rural areas,[88] and do not increase mortality rates.[89] Therefore, policy and decision-makers should consider supporting the implementation of telemonitoring and telerehabilitation interventions by providing an initial investment associated with the cost of the equipment, regulating the practice of telerehabilitation including protected time for healthcare providers, and involving in-institution information and technology services to support data transmission and enable secure remote sessions.[90,91] Future studies should explore mechanisms to reduce potential barriers associated with the use of technology-based interventions, such as lack of standardization and cost-effectiveness analyses.

Strengths and limitations

The results of this study contribute to filling a significant knowledge gap about the value of telemonitoring and telerehabilitation in the management of patients with chronic lung diseases or COVID-19. This knowledge is needed among the first priorities identified by the patients and clinicians after COVID-19 widely affected the delivery of rehabilitation services.[92,93] 63.6% of the retrieved manuscript reported on randomized controlled trials demonstrating the current need for evidence about the effectiveness of telemonitoring and telerehabilitation in patients with chronic lung diseases or COVID-19. This paper presented the evidence available as of June 2021. The generalizability of the results of this study may be influenced by the higher variability between the characteristics of the studies included such as the number and age of the patients, outcome measurements, length of the intervention, technological components involved, and additional elements included (e.g. education components, type and numbers of healthcare providers involved, etc.). Due to this heterogeneity, authors suggested a cautious interpretation of the results and compiled the studies characteristics in Table 1 to facilitate the readers' interpretation.

Conclusion

Telemonitoring and telerehabilitation interventions had a positive effect on patient exercise capacity and HRQoL and are associated with fewer healthcare use in patients with chronic lung diseases such as asthma, COPD, or post COVID-19. Furthermore, the results indicated that the outcomes of these interventions are comparable to standard care. Therefore, they are promising alternatives to support remote home-based rehabilitation in this group of patients that should be supported by policy and decision-making.

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