

Supplementary material

Table S1. Between-group differences in the outcome measures at the end of the digital rehabilitation, compared to center-based pulmonary rehabilitation or usual care.

Mode	Videoconference, supervised, in groups	Mobile/tablet application plus telephone/chat support, Individualised	Website, and possible query via website or Phone/mail support (chat) Individualised	Website with no support, Individualised
Studies	Cox et al. 2021 (n= 142) [1] Hansen et al. 2020 (n=134) [2] Tsai et al. 2017 (n=36) [3]	Cerdán-de-las-Heras et al. 2021 (n=29) [4] Cerdán-de-las-Heras et al. 2021 (n=54) [5] Kwon et al. 2018 (n=58) [6]	Bourne et al. 2017 (n=90) [7] Chaplin et al. 2017 (n=103) [8]	Tabak et al. 2014 (n=30) [9]
Digital rehabilitation vs. center-based	<p>6MWD -6.0 meters [-26; 15] [1] -6.3 meters [-22.1; 9.5] [2]</p> <p>ESWT 340 sec [153; 620] [3]</p> <p>CRQ-D -1.0 point [-3.3; 1.2] [1]</p> <p>CAT -1.6 point [-3.3; -0.1] [2]</p> <p>HADS-A -0.2 [-1.5; 1.2] [1] -1.2 [-2.3; 0.2] [2]</p> <p>HADS-D 0.5 [-0.7; 1.6] [1] -0.9 [-1.7; -0.1] [2]</p> <p>EQ-5D-VAS 0.30 [-5.74; 6.34] [2]</p> <p>CCQ [2] CCQ function -0.2 [-0.55; 0.15] CCQ mental -0.1 [-0.59; 0.39] CCQ symptom -0.1 [-0.45; 0.25] CCQ total -0.2 [-0.42; 0.2]</p> <p>PRAISE cox et al 1.0 [-1.1; 3.0]</p> <p>Hospital admission</p>	<p>6MWD 47 meters [-16.5;111.3] [5]</p> <p>GAD-7 -3.0 [-6.5; 0.5] [5]</p> <p>SGQR total -2.13 [-11.84;7.59] [5]</p> <p>Adverse events No adverse events recorded [5]</p>	<p>6MWD -11.5 meters [-65.7; 42.7] [7]</p> <p>ESWT 4.5 sec [-84; 94] [8]</p> <p>CRQ-D 2.8 points [-0.5; 6.1] [8]</p> <p>CAT -1.0 point [-2.9; 0.86] [7]</p> <p>HADS-total score -0.74 [-3.5; 0.9] [7]</p> <p>Adverse events Back pain, inguinal pain equally reported (n=3) [7]</p> <p>EQ-5D change not reported by Chaplin et al. [8]</p> <p>PRAISE change not reported by Chaplin et al. [8]</p> <p>SGRQ -4.2 [-10.5; 2.5] [7]</p>	

	<p>62 vs 50 (p=0.9) [1] 21 vs 20 (p=0.7) [2] Mortality 1 vs 2 (p=1.0) Hansne et al.</p> <p>Adverse events Drop out due to pain (n=2) in the knee and groin, both in the center-based group [2]</p>			
<p>Digital rehabilitation vs. usual care (no exercise or rehab)</p>	<p>6MWD 49 meters [-12.6; 110.6] [3]</p> <p>CRQ-D -0.1 point [-.069; 0.49] [3]</p> <p>CAT -3 points [-7; 0] [3]</p> <p>HADS-A -1 [-3; 0] [3]</p> <p>HADS-D -3 [-4; -1] [3]</p> <p>Adverse event No adverse events recorded [3]</p>	<p>6MWD 39.5 meters [-33; 116.6] [4]</p> <p>GAD-7 Group difference not calculated [4]</p> <p>KBILD Group difference not calculated [4]</p> <p>SGQR Group difference not calculated [4]</p> <p>Adverse events No adverse events recorded</p>		<p>6MWD 99.6 meters [62.9; 136.4] [9] EQ-5D-VAS (3-month) 10.8 [8.00; 13.60] [9]</p> <p>MFI-20 (3-month) Tabak et al Group difference Not calculated</p> <p>CCQ (3-month) tabak et al. Group difference not calculated</p> <p>LOS (3-month) 22days vs. 26 days [9]</p> <p>ED (3month) 5 vs. 5 [9]</p> <p>Adverse events No adverse events recorded [9]</p>

Abbreviations: 6MWD: 6-Minute Walk Distance; ESWT: Endurance Shuttle Walk Test; CAT: COPD Assessment Test; HADS-A: Hospital Anxiety and Depression Scale – Anxiety; HADS-D: Hospital Anxiety and Depression Scale – Depression; EQ-5D: EuroQol 5-Dimension; CCQ: Clinical COPD Questionnaire; CRQ-D: Chronic Respiratory Questionnaire - Dyspnea; SGRQ: St George’s; GAD-7: General Anxiety Disorder-7; mMRC: Modified Medical Research Council Dyspnoea Score; MFI-20: Multidimensional Fatigue Inventory; ED: Emergency Department; LOS: Length of Stay.

Note: Positive results favor the digital rehabilitation group, except for the mMRC, CAT and HADS.

Table S2. Summary of the interventions and outcomes of randomised controlled trials implementing technology-supported maintenance programmes after pulmonary rehabilitation (n=3).

First author (year)	Participants	Intervention group (IG)	Comparison group (CG)	Assessment period and outcomes	Main findings
Galdiz (2021) [10]	Clinically stable patients with moderate to severe COPD according to the BODE index [11] (score 3-7)	<p>IG (n=46)</p> <p>Initial PR: 8-week hospital-based outpatient PR</p> <p>Maintenance:</p> <p>Duration: 12 months</p> <p>Components: home-based maintenance telerehabilitation programme:</p> <ol style="list-style-type: none"> 1) individual action plan; 2) exercise training as in the initial PR, with pre-/post-exercise remote monitoring (HR, SpO₂, dyspnoea and leg discomfort 0-10 Borg scale); 3) access to the call centre (if any technical issues). <p>Supervision: a physiotherapist periodically monitored the exercises through the web-based platform for feedback (not specified how/when).</p> <p>Technology and equipment:</p> <ol style="list-style-type: none"> 1) Mobile phone with an app (TelePR); 2) pulse oximeter; 3) dumbbells; 4) exercise bicycle; 	<p>CG (n=48)</p> <p>Initial PR: 8-week hospital-based outpatient PR</p> <p>Maintenance: No</p> <p>Duration: 12 months</p> <p>Components: Advice to walk at least 1 hour daily or cycle as in the initial PR; general educational material</p>	<p>Assessment period:</p> <p>0 (baseline, post-PR) and 12 months</p> <p>Clinical measures:</p> <p>AECOPD</p> <p>Exercise capacity (6MWT)*</p> <p>Health-related quality of life (SF-36, CRQ)</p> <p>BODE index</p> <p>Adherence to the intervention (IG - non-adherent if no exercise performance in ≥8 weeks)^a</p>	<ul style="list-style-type: none"> • No significant between-group differences or clinically meaningful differences were found for clinical measures (p>0.05) • 56 AECOPD in IG vs. 47 in CG (p>0.05) • Dropouts/excluded from analysis: 5 IG, 8 CG • Adherence (IG): 60% • No adverse events were reported (IG)

		<p>5) web-based platform for healthcare professionals.</p> <p>Training: Instruction guide to use the mobile phone</p>			
<p>Jiménez-Reguera (2020) [12]</p>	<p>Clinically stable patients with COPD GOLD 2-4 [13]</p>	<p>IG (n=20)</p> <p>Initial PR: 8-week hospital-based outpatient PR</p> <p>Maintenance:</p> <p>Duration: 10 months</p> <p>Components: integrated care plan using a web-based app:</p> <ol style="list-style-type: none"> 1) daily recording of medication intake, exercise time, post-exercise dyspnoea (0-10 Borg scale), and mood; 2) weekly and monthly goals (not specified), warning signs, and educational content. <p>Supervision: healthcare professionals accessed data and recorded weekly/monthly goals, with minimal intervention and presence.</p> <p>Technology and equipment:</p> <ol style="list-style-type: none"> 1) Mobile phone with the HappyAir app and Google Fit app (for manual insertion of steps in the HappyAir app); 2) Pulse oximeter (manual insertion of 	<p>CG (n=24)</p> <p>Initial PR: 8-week hospital-based outpatient PR</p> <p>Maintenance: No</p> <p>Duration: 10 months</p> <p>Components: Advice to perform physical activity and breathing exercises daily</p>	<p>Assessment period:</p> <p>0 (baseline, pre-PR), 2 (post-PR), 6 and 12 months</p> <p>Clinical measures:</p> <p>Exercise capacity (6MWT)</p> <p>Health-related quality of life (CAT, SGRQ, EuroQOL-5D)</p> <p>Adherence*:</p> <p>Treatment adherence (modified CAP FISIO questionnaire)</p> <p>Adherence to physical activity (modified Morisky-Green Test)</p> <p>Adherence to the intervention (IG)</p>	<ul style="list-style-type: none"> • No between-group differences in clinical measures at 6 and 12 months ($p>0.05$) • Between-group differences in treatment adherence and physical activity adherence at 12 months ($p<0.05$) (physical activity adherence: 25% in IG vs. 11% GC) • Adherence to the app (IG only): almost daily recordings (242 records/patient in 10 months), ~92% patients exercised daily • Dropouts: 8 (various reasons)

		SpO2); 3) web-based platform for healthcare professionals. Training: one 3-4h educational session on the use of the app, after PR, plus online support aid			
Vasilopoulou (2017)[14]	Clinically stable patients with COPD GOLD 2-4 [13]	IG (n=50) Initial PR: 8-week hospital-based outpatient PR Maintenance: Duration: 12 months (144 sessions) Components: home-based maintenance telerehabilitation programme: 1) individual action plan; 2) UL/LL exercises with video demonstrations and walking drills, and remote monitoring post-exercise (HR, SpO2, dyspnoea and leg discomfort 0-10 Borg Scale); 3) daily steps, spirometry, oximetry and questionnaires collected twice weekly (SGRQ, CAT, mMRC) or monthly (HADS); 4) access to a call centre 5 days/week; 5) psychological support; 6) dietary and self-management support via weekly contacts via telephone or	CG1 (n=50) Initial PR: 8-week hospital-based outpatient PR Maintenance: Duration: 12 months (96 sessions) Components: hospital-based outpatient maintenance rehabilitation: 1) twice weekly exercise training; 2) dietary advice; 3) instructions on breathing exercises and self-management (early recognition of an AECOPD). CG2 (n=50) Initial PR: No Maintenance: No Duration: 12 months Components: usual care without	Assessment period: 0 (baseline, pre-PR), 2 (post-PR) and 14 months Clinical measures: AECOPD* exercise capacity (CPET, 6MWT) physical activity (Actigraph GT3X) health-related quality of life and symptoms (SGRQ, CAT, mMRC) Healthcare use: hospitalisations* ED visits* Adherence rate (actual number of sessions/total expected number of sessions*100)	<ul style="list-style-type: none"> • Lower rate of AECOPD and hospitalisations in the IG and CG1 vs. CG2 (p<0.001); • Lower rate of ED visits in the IG vs. CG1 and CG2 (p<0.001) • Maintenance of clinical/statistical improvements in exercise capacity (p<0.01), SGRQ, CAT and mMRC, and physical activity (p<0.05) in the IG and CG1 vs. CG2; • Adherence (IG): 93.5% (all components >90% except HADS monitoring) • Dropouts: 3 in the initial PR (IG)

		<p>videoconference with healthcare professionals.</p> <p>Supervision: data reviewed by healthcare professionals 3-4 times/week</p> <p>Technology and equipment:</p> <p>1) Tablet for manual insertion of steps (pedometer), remote monitoring and responses to questionnaires;</p> <p>2) device to collect vital signs (HR, SpO2) and spirometry, and transmit data to the tablet;</p> <p>3) web-based platform for healthcare professionals.</p> <p>Training: patients and their relatives trained to use the equipment during the initial PR</p>	<p>initial PR (n=50); optimal pharmacotherapy and vaccination; regular follow-up by a respiratory physician; training on early recognition of an AECOPD</p>		
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Note: Primary endpoints of studies are identified with *.

Legend: AECOPD, acute exacerbation of COPD; CAT, COPD Assessment Test; CG, Control group; COPD, chronic obstructive pulmonary disease; CPET, cardiopulmonary exercise test; HADS, Hospital Anxiety and Depression Scale; HR, heart rate; IG, Intervention group; mMRC, modified Medical Research Council Dyspnoea Scale; PR, Pulmonary rehabilitation; SGRQ, Saint George Respiratory Questionnaire; SpO2, peripheral oxygen saturation; 6MWT, 6-minute walk test.

Table S3. National and international privacy protection laws, regulations and best practices that should be considered during technology design and implementation.

Name	Description	Source
European Union (EU) General Data Protection Regulation (GDPR) 2016/679	European legal framework with the purpose of protecting the collection of personal/confidential data. It contains information on the principles relating to processing of personal data and individual rights (e.g., individual’s consent for data collection/transfer).	https://eur-lex.europa.eu/eli/reg/2016/679/oj
European Union Agency for Network and Information Security (ENISA)	ENISA is a centre of network and information security expertise for the EU, its member states, the private sector and EU citizens, working with these groups to develop advice and recommendations on good practice in information security. network and information security throughout the EU. It has several relevant reports, including one which covers functional requirements for a potential ICT security certification scheme for a healthcare sector (second link)[15].	www.enisa.europa.eu https://www.enisa.europa.eu/publications/healthcare-certification
Handbook on European data protection law (2018)	This document provides an overview of the EU and Council of Europe legal frameworks and summarizes major rulings of the EU Court of Justice and the European Court of Human Rights.	https://bit.ly/3Mjt4z2
Health Insurance Portability and Accountability Act (HIPAA) Privacy and Security Rules (US)	The HIPAA Privacy Rule governs, in general, the use and disclosures of protected health information in the United States. The HIPAA Security Rule contains security standards for protecting electronic protected health information. The healthcare sector has heightened vulnerability to cyber attacks, and these incidents can lead to suboptimal care or harm to people.	https://www.hhs.gov/hipaa/for-professionals/index.html
NIST Health IT	This programme aims to help improve the quality and availability of healthcare and reduce	https://www.nist.gov/healthcare

programme	healthcare costs by enabling the development and harmonization of standards for health IT technologies, creating a health IT technology testing infrastructure, and supporting the usability of health IT technologies, among others. They have also a White paper on “Adopting the NIST Cybersecurity Framework in Healthcare” (second link).	https://docs.broadcom.com/doc/adopting-the-nist-cybersecurity-framework-in-healthcare-en
RECODE Health	Checklist and other resources to support stakeholders involved in digital health research process, aiming to increase awareness of ethical principles and practices from the earliest stages of technology design to the deployment of digital health research. It includes a framework which addresses four intersecting domains including: access and usability, risks and benefits, privacy, and data management.	https://recode.health/about/
SANS Health Care Security Resources	This web platform on cybersecurity aims to provide training and education for cybersecurity professionals and it has a specific section on cybersecurity in health care, with information provided in different formats including webcasts, whitepapers, and other resources.	https://www.sans.org/blog/sans-healthcare-security-resources/
WHO Practical guide for monitoring and evaluating digital health interventions[16]	This document provides guidance to improve the quality and value of monitoring and evaluation efforts in the context of digital health interventions, including technical functionality and feasibility.	https://apps.who.int/iris/handle/10665/252183

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