

RESEARCH

Open Access



Sustaining training effects through physical activity coaching (STEP): a randomized controlled trial

Matthias Loeckx^{1,2†}, Fernanda M. Rodrigues^{1,2,3†}, Astrid Blondeel^{1,2}, Stephanie Everaerts^{2,4}, Wim Janssens^{2,4}, Heleen Demeyer^{1,2,5†} and Thierry Troosters^{1,2*†}

Abstract

Background Pulmonary rehabilitation (PR) programs improve physical fitness, symptoms and quality of life (QoL) of patients with COPD. However, improved physical activity (PA) is not guaranteed after PR and the clinical benefits fade off after PR discharge. We aimed to investigate whether a 9 months PA-telecoaching program is able to improve PA of patients with COPD, after 3 months of PR and if this leads to maintenance of PR-acquired benefits.

Methods Patients with COPD enrolled in a 6-month PR program were randomized to a (semi-automated) PA-telecoaching program or usual care, 3 months after PR initiation. The intervention consisted of a smartphone application with individual targets and feedback (for 6 months) and self-monitoring with a step counter (for 9 months). Patients were followed up for 9 months after randomization. Primary outcome was PA (daily step count by accelerometry), secondary outcomes were exercise tolerance, quadriceps force, dyspnea and QoL.

Results Seventy-three patients were included (mean \pm SD: 65 \pm 7 years, FEV₁ 49 \pm 19%, 6MWD 506 \pm 75 m, PA 5225 \pm 2646 steps/day). The intervention group presented a significant improvement in steps/day at every visit compared to usual care (between-group differences mean \pm SE: 1431 \pm 555 steps/day at 9 months after randomization, $p=0.01$). Secondary outcomes did not differ between the groups.

Conclusion The semi-automated PA-telecoaching program implemented after 3 months of PR was effective to improve the amount of PA (steps/day) during PR and after follow-up. However, this was not accompanied by the maintenance of other PR-acquired benefits.

Trial registration ClinicalTrials.gov. Identifier: NCT02702791. Retrospectively registered on March 9, 2016. Start study October 2015. <https://clinicaltrials.gov/ct2/show/NCT02702791?term=NCT02702791&draw=2&rank=1>.

Keywords Physical activity, Chronic obstructive pulmonary disease, Rehabilitation and telemedicine

[†]Matthias Loeckx, Fernanda M Rodrigues and Heleen Demeyer, Thierry Troosters contributed equally.

*Correspondence:
Thierry Troosters
thierry.troosters@kuleuven.be

¹Department of Rehabilitation Sciences, KU Leuven, Leuven, Belgium

²Respiratory division, University Hospitals Leuven, Leuven, Belgium

³Department of Medicine, Western of Sao Paulo University (UNOESTE), Guarujá, Brazil

⁴Department of Chronic Diseases and Metabolism, KU Leuven, Leuven, Belgium

⁵Department of Rehabilitation Sciences, Ghent University, Ghent, Belgium



© The Author(s) 2023. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>. The Creative Commons Public Domain Dedication waiver (<http://creativecommons.org/publicdomain/zero/1.0/>) applies to the data made available in this article, unless otherwise stated in a credit line to the data.

Background

Multidisciplinary pulmonary rehabilitation (PR) programs result in important and clinically relevant improvements for patients with symptomatic COPD, such as improved functional exercise tolerance, muscle force, symptoms of dyspnea and quality of life (QoL) [1]. Unfortunately, these effects are short-term and tend to wear off in the majority of patients after PR-discharge [2, 3]. The lack of maintenance of these clinical benefits might be linked to a continued lack of physical activity (PA) upon completion of PR. Indeed, patients with COPD, even in early stages of the disease, present decreased PA [4–6] and PA does not restore spontaneously after PR [7]. Therefore, the American Thoracic Society (ATS) and European Respiratory Society (ERS) statement on PR highlights the promotion of PA as one of the goals of PR as long-term health-enhancing behavior [8].

Programs aiming to improve PA outside a PR-setting, using self-monitoring and feedback strategies (i.e. step counters) have been shown effective in several (short-term) trials [9–12]. Recently, such PA promotion programs have been implemented as part of a PR-program, however, with variable success and mostly focusing on short-term PA improvements [13–17]. A reason for lack of success might be the timing to start such programs. As PA interventions are more effective in patients with a better functional capacity, we speculate that such interventions may be more effective when initiated after an initial intensive PR-phase that increases exercise tolerance [7]. One recently published randomized controlled trial (RCT) starting PA coaching at the end of a three-week inpatient-PR program showed an increased PA 6 months later [18].

Furthermore, the effect on the maintenance of PR-acquired benefits of programs using wearable technology to promote PA have not been explored in depth yet. It is tempting to speculate that enhanced PA may indeed be crucial to maintain the benefits of a PR-program.

We conducted a RCT which aimed to investigate (1) Whether implementation of a (semi-automated) PA-telecoaching program, started after 3 months of PR, was effective at increasing PA after 9 months of follow-up (i.e. the long-term effects) and (2) If this PA program resulted in maintained PR-acquired benefits in terms of physical fitness (exercise tolerance, skeletal muscle strength), symptoms and health-related QoL.

Methods

Subjects

Patients with COPD who enrolled in the multidisciplinary, six months outpatient PR at the Leuven Hospital were screened for eligibility. After completing three months of PR and after one-week PA assessment,

patients were invited to participate to the STEP ('Sustaining Training Effects through Physical activity promotion') trial. Main inclusion criteria included being older than 40 years, having cognitive ability to work with electronic devices and absence of comorbidities that interfere with the normal biomechanical movement patterns and therefore PA performance. Further details are outlined in the additional file 1.

Design

This was a mono-center, 1:1 prospective RCT (details of randomization outlined in additional file 1). At three months of the 6 months PR-program, eligible patients were included in the study after signing a written informed consent. The trial was registered at clinicaltrials.gov (NCT02702791) and was approved by the local ethics committee (S57963). It consisted of four visits: (1) a visit at randomization, upon completion of 3 months of PR (i.e. start of the study – V0), (2) a visit at the end of PR (i.e. upon completion of 6 months of PR and 3 months after randomization – V1), (3) a visit 3 months after discharge from PR and 6 months after randomization (V2) and (4) a visit 6 months after discharge from PR and 9 months after randomization (V3) (Fig. 1). At the start of PR (i.e. 3 months prior to randomization – V-1), clinical data were assessed as part of PR routine assessments. Randomization took place after completing the first three months of rehabilitation in order to allow the focus on enhancing physical fitness in the first part of the rehabilitation process [19].

The first randomization visit for the first patient took place on October 2015. Last patient last visit took place on September 2019.

Interventions

Pulmonary rehabilitation program (PR)

The standard six-months multidisciplinary program of the Leuven Hospital, previously described in detail [20], was the setting for this study. Patients allocated to the intervention (IG) and usual care groups (UCG) underwent the same PR-program and PR health care providers were blinded to the randomization assignment. Exercise sessions were delivered at a frequency of three times a week in the first three months and twice a week in the second. If patients continued some form of exercise training after PR-discharge, this information was recorded in their file.

Usual Care

At randomization, patients in the UCG received an information leaflet explaining the importance of and tips on how to become more physically active. Furthermore, at V0, an interview was conducted to assess the level of the patients' motivation and self-efficacy towards increasing

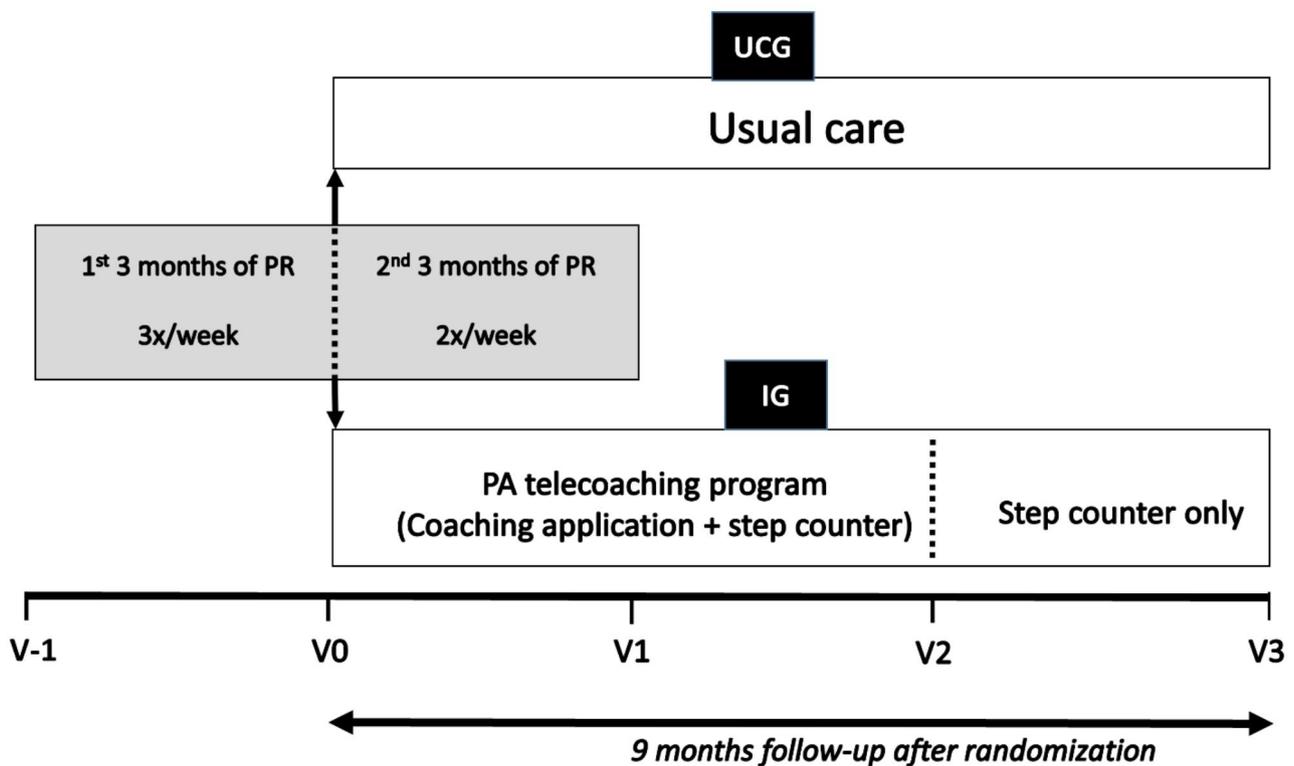


Fig. 1 Study design. Four study visits: a visit at randomization (i.e. after 3 months of PR; V0), a visit at the end of PR (i.e. after 6 months of PR; V1), a visit after 3 months of follow-up from PR (V2) and a visit after 6 months of follow-up from PR (V3). Data at the start of PR (i.e. 3 months before randomization) were also used for analysis (V-1). Patients were followed up for 9 months after initiation of the PA telecoaching program. PR, pulmonary rehabilitation; V, visit; UCG, usual care group; IG, intervention group

and maintaining their PA level throughout the trial (likert-type scale ranging from 0 (lowest) to 10 (highest)).

Intervention Group

On top of usual care, patients in the IG received a PA-telecoaching program very similar to the one used previously (NCT02158065–MrPAPP trial), which was proven effective on short-term PA [9, 21]. This intervention consisted of a step counter worn at the waist which provided direct feedback on the number of steps/day patients performed and a project-tailored, semi-automated coaching application on a smartphone (Linkcare® application, Barcelona, Spain) providing daily goal setting, weekly feedback and educational messages. Further details regarding the coaching intervention can be found in the additional file 1.

At randomization, in addition to the assessment of motivation and self-efficacy, the interview in the IG elaborated on barriers of being active, personalized strategies to become more active and a specific action plan was agreed and delivered to the patients, so they could consult it during the intervention.

Assessments

Prior to each visit, PA was objectively assessed with the Dynaport Movemonitor (DAM, McRoberts BV, The Hague, the Netherlands) and the Actigraph GT3x (ACT, Actigraph LLC Pensacola, Florida, USA), two validated accelerometers [22, 23]. As recommended [24], patients were instructed to wear the monitors for seven consecutive days during waking hours. Day-by-day data were exported using the company's algorithms to retrieve wearing time (DAM and ACT), steps per day (DAM and ACT), movement intensity during walking (MI - DAM) and time in at least moderate intensity activity (MVPA - DAM and ACT). All valid weekdays (at least 8 h of wear time in each) were included in the analyses. A PA assessment was judged adequate and representative if it included at least 2 valid days [24]. DAM was a priori chosen as the primary PA monitor. In case of missing PA data from DAM (e.g. due to technical problems), ACT data were used as input data for multiple imputation to be as complete as possible. Patients did not attend supervised PR-sessions during the PA assessments.

For patient characterization, spirometry, lung volumes and diffusion capacity of the lung for carbon monoxide were measured at V0. Secondary outcomes were (measured at V0, V1, V3) (1) maximal exercise tolerance

(cycling cardiopulmonary exercise testing (CPET)), (2) endurance tolerance (endurance cycling test at 75% of the maximal workload achieved on the CPET at V0), (3) functional exercise tolerance (six minutes walking distance (6MWD)), (4) quadriceps force (QF) (isometric maximal voluntary contraction against a fixed strain gauge. Results were normalized for body weight (Nm/kg)); and (5) symptoms of dyspnea (by modified Medical Research Council (mMRC) for dyspnea) and QoL (Chronic respiratory disease questionnaire (CRDQ)) [25]. 6MWD and QF were additionally assessed at V2.

Exploratory outcomes (measured at V-1 and V3) included (1) body composition (total body mass, total body T-score and femoral neck T-score) from a dual energy X-ray absorptiometry (DEXA) scan and (2) Fasting venous blood analysis for levels of glucose, insulin, triglycerides, high-density lipoprotein (HDL) and low-density lipoprotein (LDL). The occurrence and severity of acute exacerbations as well as adverse events were collected during the trial. Further details on all measurements can be found in the additional file 1.

Statistical analysis

Analyses were performed using SAS Software version 9.4. Values were expressed as mean \pm standard deviation (SD) or median [percentile 25–percentile 75] (in case of non-normal distribution – Shapiro-Wilk test) or as numbers (%) in case of frequencies. Statistical significance was set a priori as $p < 0.05$ for all analyses. All randomized patients were invited for follow-up assessments and included in the Intention-to-treat analysis, even if they stopped using the intervention. The overall effects of the PR-program from V-1 to V0 were descriptively calculated for all patients from assessments obtained in clinical routine.

First, to assess the effect of the PA-telecoaching program on change in PA (i.e. steps/day, MVPA and MI), mixed model analyses were used retrieving the interaction effects at each visit as main results. PA at V0 was chosen as reference. The models were adjusted for daylight as a proxy for seasonality [26]. Multiple imputation through chain Eq. (20 times) was performed in case of missing values of DAM. Day-by-day data of steps and MVPA which were considered to be missing at random were imputed using regression models based on ACT data (proc mi). A weekly average was calculated per multiple imputation dataset and used in further analyses. As a sensitivity analysis, we repeated the main PA analyses based on the complete DAM dataset.

Second, to analyze the effect of the PA-telecoaching program on change of PR-acquired benefits similar mixed models were used for secondary outcomes (maximal, endurance and functional exercise tolerance, quadriceps force, symptoms of dyspnea and QoL). The change

in exploratory outcomes (body weight, bone mineral density, blood glucose, lipids and insulin profile) from V-1 (start PR, i.e. 3 months before randomization) to V3 were analysed via ANCOVA analyses, adjusting for values at randomization (V0).

Finally, we explored the difference in proportion of patients with long-term success between UCG and IG using chi-square analyses. Long-term success was defined as an increase above the minimal important difference (MID) at V3 as compared to start of PR (V-1) in terms of (A) functional exercise tolerance (i.e. $\Delta 6\text{MWD} \geq 30$ m), (B) symptoms of dyspnea (CRDQ score ≥ 2.5 points) and (C) QoL (CRDQ score ≥ 10 points) [27].

Sample size calculation

Sample size calculation was based on the primary research question (i.e. effectiveness of the intervention on daily step count). To obtain a power of 80%, expecting a drop-out rate of 20%, a total of 82 patients needed to be included in this study (based on a between group difference of 1785 steps/day, SD of 2505 and α -level of 0.05). These data were based on preliminary results of the tele coaching study running in our center [9]. Because of the slower than expected recruitment, the power analysis was recalculated based on the final results of the tele coaching study [9] and the actual drop out (12%). Therefore, recruitment was stopped at 73 patients (power 80%, alpha 0.05).

Results

Patient characteristics

In total, 73 patients were randomized to either the UCG ($n=37$) or IG ($n=36$) after 3 months of PR, of which 65 were followed up until the end of trial (Fig. 2). Patients' characteristics at randomization (V0) are displayed in Table 1 and Additional file 2. Patients in both groups had a low PA (mean 5225 ± 2646 steps/day), a modestly reduced exercise tolerance (6MWD $80 \pm 12\%$ predicted normal) but QF returned to expected normal values ($99 \pm 26\%$ of predicted normal value) [28]. The randomized patients wore the DAM for a mean of 4.82 ± 0.46 weekdays with a mean wearing time of 872 ± 98 min/day. Patients included in both groups presented similar high levels of motivation to increase PA (9 [8–10] out of 10 for both groups, $p=0.34$) and self-efficacy to become more physically active scores of 8 [6–9] out of 10 in the UCG and 8 [7–9] out of 10 in the IG ($p=0.75$).

Characterization of patients at the start of PR (V-1, 3 months before randomization) is included in the Additional file 3. Overall, changes in PA in the first 3 months of PR (V-1 to V0) were modest ($\Delta 725 \pm 1822$ steps/day and $\Delta 8 \pm 24$ min/day MVPA). As expected, patients experienced, at the group level, prior to randomization (V-1 to V0) meaningful improvements in maximal

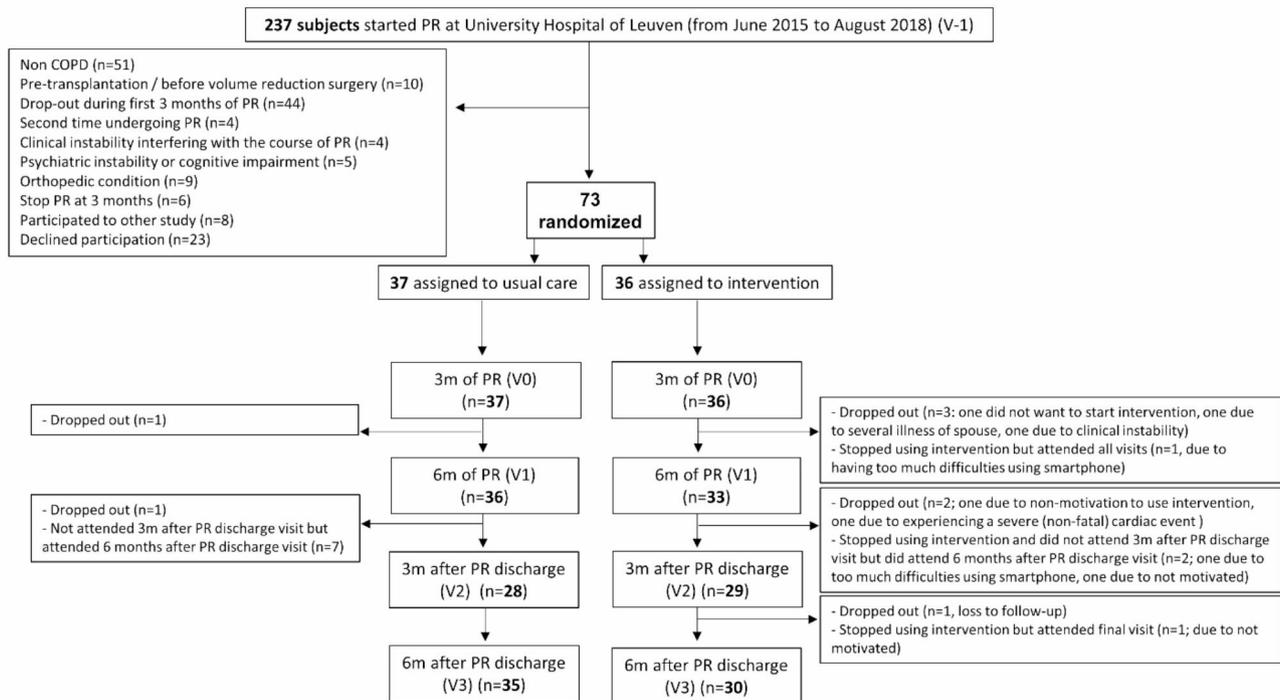


Fig. 2 Flow diagram of STEP trial. Numbers refer to the total number of patients evaluated at each timepoint, independently of obtaining valid physical activity measures. PR, pulmonary rehabilitation program; COPD, Chronic Obstructive Pulmonary Disease; m, months; V, visit. Each visit (i.e. V-1, V0, V1, V2, V3) has an interval of 3 months in between

Table 1 Patient characteristics at randomization

	UCG (n=37)	IG (n=36)	All (n=73)
Age (years)	66 ± 8	62 ± 7	65 ± 7
Gender [n (% male)]	20 (54%)	22 (61%)	42 (58%)
BMI (kg/m ²)	26 ± 5	24 ± 6	25 ± 5
FEV ₁ (% pred)	49 ± 17	50 ± 21	49 ± 19
TL _{CO} (% pred)	50 ± 18	50 ± 14	50 (16)
VO ₂ peak (ml/min/kg)	15.9 ± 4.2	18.4 ± 4.0	16.8 ± 4.2
VO ₂ peak (% pred)	77 ± 23	78 ± 42	77 ± 33
Endurance time CWRT (s)	321 ± 143	374 ± 212	345 ± 179
6MWD (m)	499 ± 72	512 ± 79	506 ± 75
6MWD (% pred)	81 ± 12	79 ± 11	80 ± 12
Max isom QF (Nm)	137 ± 41	133 ± 52	135 ± 47
Max isom QF (Nm/kg)	1.83 ± 0.47	1.94 ± 0.55	1.89 ± 0.51
CRDQ _{dyspnea} (points)	22 ± 6	20 ± 5	21 ± 6
CRDQ _{total} (points)	93 ± 15	89 ± 12	91 ± 14
PA (steps/day)	5530 ± 2910	4910 ± 2352	5225 ± 2646
Time spent in MVPA (min/day)	87 ± 40	80 ± 31	83 ± 36
Movement intensity (m/s ²)	1.68 ± 0.26	1.78 ± 0.21	1.73 ± 0.24
Daylight (min/day)	763 ± 183	760 ± 188	761 ± 184
Wearing time (min/day)	873 ± 95	870 ± 102	872 ± 98
Valid weekdays (n)	4.85 ± 0.44	4.78 ± 0.49	4.82 ± 0.46

Values presented as mean ± standard deviation or as number (percentage). UCG, usual care group; IG, intervention group; BMI, n, number of patients; body mass index; kg, kilograms; m, meters; FEV₁, forced expiratory volume in 1 s; pred, predicted; FEV₁/FVC, tiffeneau index; TL_{CO}, diffusing capacity for carbon monoxide; ; VO₂, oxygen uptake; ml, millilitres; min, minutes; CWRT, constant work rate test; s, seconds; 6MWD, six minutes walking distance; Max, maximal; isom, isometric; QF, quadriceps force; Nm, Newtonmeters; CRDQ, Chronic Respiratory Disease Questionnaire; PA, physical activity; MVPA, moderate to vigorous PA.; PA data is based on DAM data (n=65)

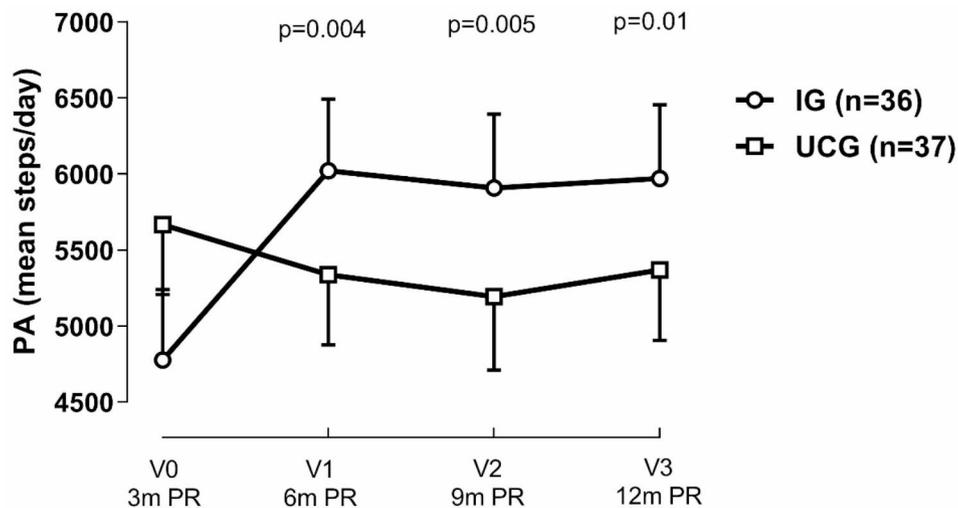


Fig. 3 Comparison of the changes in PA between patients from both the IG and UCG, adjusted for daylight at each visit point. p-values indicate the interaction effect (with V0 as the reference). PA; physical activity; IG, intervention group; UCG, usual care group; n, number; m, months; PR, pulmonary rehabilitation. Data based on multiple imputation

Table 2 Comparison of changes in PA between IG and UCG groups. V0 was considered the reference at mixed model analysis

	V0	V1	V2	V3
PA (steps/day)				
UCG	Ref	-313 ± 315	-462 ± 342	-278 ± 318
IG		1277 ± 433	1228 ± 453	1177 ± 457
Between groups changes		1544 ± 534	1605 ± 570	1431 ± 555
p value		0.004	0.005	0.01
Time spent in MVPA (min/day)				
UCG	Ref	-3 ± 5	-4 ± 5	-0 ± 5
IG		11 ± 6	13 ± 6	10 ± 6
Between groups changes		13 ± 8	16 ± 8	10 ± 8
p value		0.0802	0.0466	0.2107
Movement intensity (m/s²)				
UCG	Ref	-0.018 ± 0.024	0.011 ± 0.027	0.001 ± 0.024
IG		0.057 ± 0.037	0.058 ± 0.040	-0.001 ± 0.039
Between groups changes		0.07 ± 0.04	0.04 ± 0.05	-0.01 ± 0.04
p value		0.0869	0.3599	0.8840

Values presented as estimates ± standard error obtained from the mixed model analysis adjusted for daylight. PA, physical activity; MVPA, moderate to vigorous PA. UCG, usual care group; IG, intervention group; min; minutes; m, meter; s, seconds. In case of missing data (for steps/day and MVPA) from the Dynaport Activity Monitor, multiple imputation was performed with the data from the Actigraph as outlined in the methodology section. At V1, V2 and V3, interaction effect with V0 as reference value are displayed

and functional exercise tolerance and QoL (Δ Work rate (WR) = 10 ± 115 Watts, Δ 6MWD = 43 ± 28 m and Δ CRDQ total = 14 ± 12 points).

Intervention effect on physical activity

Patients who received the PA-telecoaching intervention presented clinically important improvements in steps/day compared to patients in the UCG, at each time point after randomization (Fig. 3). Changes in time spent in

MVPA and movement intensity during walking were not significantly different between groups at the end of follow-up (Table 2). The sensitivity analyses based on the complete dataset provided very similar results (Additional file 4).

Effect on secondary outcomes

The PA-telecoaching program did not induce significant improvements in terms of maximal, endurance and

functional exercise tolerance, muscle strength and QoL as compared to usual care (Table 3 & Additional file 5), at none of the timepoints.

Effect on exploratory outcomes

The effect of the PA-telecoaching program on exploratory outcomes is displayed in Table 4. No significant differences between patients in the IG and the UCG group in terms of body weight, Bone mineral density (BMD) or markers of osteoporosis were observed. Similarly, no difference was found in blood markers except for a trend towards a reduction in fasted blood glucose favoring the IG group ($p=0.06$; Table 4). A similar number of patients of both the IG and UCG group experienced MID in functional exercise tolerance, symptoms of dyspnea and QoL [23] from V-1 to V3 (Additional file 6).

Adverse events and follow-up

Twenty patients (57%) experienced at least one (moderate or severe) acute exacerbation during the study in the UCG compared to 14 (47%) patients in the IG ($p=0.46$). A total of 51 non-respiratory adverse events were reported during the study period, of which 20 (39%) occurred in the IG and 31 (61%) in the UCG. 47% of them led to a hospital admission. The adverse events were cardiovascular (25%), musculoskeletal (24%), internal (4%), cancer (2%) and other (45%). Two (swollen knee in UCG, joint pain in IG) were considered as “unlikely” related to the study, the other as “not” related to the study. One event (viral gastroenteritis) led to study discontinuation.

After finishing 6 months of PR and 9 months after randomization, slightly more (65%) patients from the UCG continued supervised training (i.e. typically 1x/week in primary/community care) compared to the IG (42% $p=0.14$).

Table 3 Comparison of the changes in secondary outcomes between IG and UCG

	V0	V1	V2	V3
VO₂peak (ml/min/kg)				
UCG	Ref	-0.3±0.5		-0.6±0.5
IG		-1.0±0.5		-1.3±0.5
Between groups changes		-0.70±0.75		-0.66±0.76
p value		0.3525		0.3890
Endurance duration				
CWRT (s)				
UCG	Ref	4±33		-64±33
IG		43±41		21±42
Between groups changes		35±52		87±53
p value		0.5033		0.1039
6MWD (meters)				
UCG	Ref	-7±8	-34±8	-26±8
IG		-6±8	-28±8	-20±8
Between groups changes		2±11	6±12	7±11
p value		0.8903	0.5923	0.5327
Max isom QF (Nm/kg)				
UCG	Ref	-0.01±0.06	0.04±0.07	0.02±0.06
IG		-0.04±0.05	0.01±0.05	-0.06±0.05
Between groups changes		-0.05±0.08	-0.04±0.08	-0.08±0.80
p value		0.5543	0.6445	0.3037
CRDQ_{dyspnea} (points)				
UCG	Ref	2±1		0.5±1
IG		4±1		1±1
Between groups changes		1.58±1.15		0.58±1.18
p value		0.1722		0.6232
CRDQ_{total} (points)				
UCG	Ref	3.3±2		-2±2
IG		7.4±2		-0.4±2
Between groups changes		4.05±2.95		1.81±3.09
p value		0.1727		0.5603

Values presented as estimates±standard error. m- months, PR, pulmonary rehabilitation program; VO₂, oxygen uptake; CWRT, constant work rate test; 6MWD, six minutes walking distance; isom, isometric; QF, quadriceps force; CRDQ, Chronic Respiratory Disease Questionnaire; VO₂peak, peak oxygen uptake; ml, millilitres; min, minutes; kg, kilogram; s, seconds Isom, isometric; Nm, Newton meters. At V1, V2 and V3, interaction effect with V0 as reference value are displayed in this table

Table 4 Effect of PA-telecoaching intervention on exploratory outcomes

	UCG Mean (SD)	IG Mean (SD)	Between group Mean(SE)	P value
Bone Mineral Density (DEXA scan)				
Δ T-Score total body	0±0.37	0±0.29	-0.09 (0.11)	0.4231
Δ T-Score femoral neck	-0.02±0.21	-0.11±0.38	-0.06 (0.08)	0.4789
Fasting Blood profile				
Δ Glucose (mg/dL)	1±11	-9±18	-6.80 (3.5)	0.0569
Δ Insulin (mg/dL)	-12±45	0±46	15 (13)	0.2676
Δ Triglycerides (mg/dL)	-7±33	-1±40	7.9 (8.6)	0.3668
Δ HDL cholesterol (mg/dL)	0±9	2±12	1.10 (2.9)	0.7070
Δ LDL cholesterol (mg/dL)	8±18	-2±26	-8.5 (6.7)	0.2085

Data are expressed as mean±standard deviation. UCG, usual care group; IG, intervention group; DEXA, dual energy X-ray absorptiometry; g, gram; mg, milligram; dL, deciliters; HDL, high-density lipoprotein; LDL, low-density lipoprotein. Between group differences and p-values are based on ANVOCA analyses and expressed as mean±SE.

Discussion

The semi-automated PA-telecoaching program implemented at 3 months of PR was able to induce a sustained and clinically significant [29] improvement in the amount of PA (i.e. steps/day) in patients with COPD. Other clinical benefits in physical fitness, symptoms and QoL were not better maintained in the IG compared to the UCG, 9 months after initiation of the PA telecoaching intervention.

Despite the ATS/ERS recommendation of including physical activity promotion within PR [8], it is still not clear how this is best implemented [30]. Real-time feedback combined with individual target setting are considered important components in interventions to change general behaviour [31], including PA [32, 33]. Previous studies showed conflicting results regarding change in PA when adding PA coaching among patients with COPD undergoing PR [13–18]. In contrast to our findings, four of these studies demonstrated that PA coaching interventions including PA counselling and/or step counter-based targets embedded in a PR program did not improve PA in the short [13, 16, 34] or long-term [1, 34].

A first explanation for this apparent discrepancy across trials, is the timing of the PA-coaching intervention. Providing PA coaching interventions at the start of a PR program might be overwhelming and unrealistic in these symptomatic, inactive and deconditioned patients [13, 16, 34]. In patients with better preserved exercise tolerance (i.e. 6MWD of 494 m [15] vs. range of 395–448 m on the 6MWD in the other trials [13, 14, 16, 34]), a PA coaching intervention including both PA-counseling and step-counter based targets was effective started together with PR [15]. The level of exercise tolerance is a second factor that might explain conflicting findings across studies. Indeed, a better preserved exercise tolerance has

been previously shown to improve the likelihood of PA increase [19]. As patients who are referred to PR present limiting functional exercise tolerance [35], our study was designed to implement the PA-telecoaching intervention at 3 months of PR, allowing prior improvement for exercise tolerance before the start of the PA coaching. The magnitude of the intervention effect was in line with a previous large multicentre study in stable patients not enrolled in PR program [9] and a recently published RCT starting coaching after a short inpatient-PR [18].

The present study is supported by the “Capability, Opportunity & Motivation” for Behaviour change (COM-B) system, a framework for understanding behaviour (change) from Michie and colleagues [36]. In terms of ‘capability’, our design (starting after an initial period of PR only) allowed optimization of physical fitness (capacity) during the initial three months of PR (i.e. before start of the PA-telecoaching). ‘Opportunity’ (to become physically active) was addressed at the interview in the IG before the start and was further supported by telephone contacts during the intervention during which barriers and facilitators were discussed. ‘Motivation’ was targeted with automatic messages which patients received on their smartphone (daily display of activity goals, daily and weekly feedback, cumulative achievements and positive tips to keep active) and telephone contacts. Furthermore, being monitored and supported by the investigators was considered an important motivation tool, based on previous patients’ feedback on this PA-telecoaching intervention [21].

Despite the significant effect on the amount of PA, this intervention did not result in sustained training benefits. The latter could have been expected as several of these PR training benefits are known to be positively associated with PA in patients with COPD [37]. The end points

of exercise tolerance, muscle force, dyspnea symptoms and QoL that were initially enhanced with PR were not different between groups at the follow-up visit and a comparable and significant proportion of patients from both groups presented minimal important improvements of these end points at follow-up. Thus, the clinically relevant increase in step count [29], in absence of significant improvements in PA intensity, did not prevent patients to lose PR-benefits over time. Some possible factors explaining these findings are: (1) the telecoaching intervention was not able to prevent exacerbations, known to impact on physical fitness, QoL and symptoms; (2) This PA-telecoaching intervention focused primarily on increasing the number of steps/day using the step counter to provide direct feedback. This measure is a relevant PA outcome which is easy to measure and well understood by patients [38, 39]. While the intervention improved the number of steps per day, there was little cross over to enhanced physical fitness. Using steps as motivation does not include incentives towards intensity of the PA. In line with the principles of exercise training, in order to achieve significant physiologic benefits, progressive overload (intensity) has been proven to be important [40]. While it is possible that the effect size (0.30 at V3 and 0.34 at V1 for step count) is too small to render significant physiologic effect, it is more plausible to speculate that, to maintain benefits of PR, focus on intensity needs to be implemented in future studies. The PA intervention by Mendoza et al. [32], although achieving larger effects on PA (effect size of 0.48), did not lead to clinically relevant improvements in functional exercise tolerance (6MWD), either. Furthermore, a recent study suggests that this can be achieved by embedding exercise training (e.g. in the form of a set of exercises embedded in the coaching app) would allow to achieve maintained fitness, on top of improved physical activity [18]; and (3) Numerically more patients from the UCG continued supervised exercise training in other facilities after PR-discharge. This could partially contribute to the lack of between-group differences because they could continue to perform systematically planned exercises (cfr. progressive overload). Our data corroborate with others [18] also reporting no additional benefits on exercise tolerance when adding telecoaching and home exercises after PR. Interestingly, the latter study did report a better health status at follow-up in patients following the telecoaching intervention. The addition of a self-directed strength training program on top of PA goal setting might partly explain this difference. Importantly, the analyses on the impact on PR-benefits is a secondary outcome of this study. The present study was powered to detect a change in PA. Further larger studies are needed to confirm our findings, but from our data there may be more merit in integrating PA at sufficient intensity rather than to

introduce only larger volumes of PA if maintenance of physiologic benefits is the goal.

In line with the results on exercise tolerance, muscle force, quality of life, body composition, BMD and blood markers of insulin and lipids were not clinically better in the IG at the end of the trial. A decrease in the level of fasted blood glucose in the IG was noted compared to the UCG, which could lower the incidence risk for diabetes [41]. The latter decrease was numerically higher than the decrease in fasted blood glucose levels reported from diet and PA-promotion programs in adults at risk of type 2 diabetes (mean [95% Confidence Intervals]-2.2 mg/dl [-3.6 to -0.9 mg/dL] [41]. However, this finding needs replication in a larger study. Increasing PA levels, nevertheless, remains an important health advice in any patient at risk of developing type II diabetes and PA-telecoaching can be a useful tool in this context.

Strengths and limitations

To the best of our knowledge, this trial is one of the first to test a long-term effect of a PA intervention and to investigate the causal relationship between PA and PR-benefits using an interventional design after 3 months of PR and 9 months of follow-up. It therefore helps to understand the importance of achieving the long-term goals of PR as described in the guidelines for PR by major respiratory Societies [8]. The present PA-telecoaching intervention was specifically tailored to patients with COPD and took several aspects of intervention implementation into account which were reported in the previous RCT [21].

Due to the nature of the intervention, patients could not be blinded for group allocation. PR-sessions were performed in group and contamination could not be prevented. This study was conducted in a 6-month outpatient PR setting. This needs to be considered for the external validity of our findings. However, the actual PA-telecoaching intervention started after 3 months of PR. The study by Spielmanns et al. is a first external validation that the concept of starting PA coaching after shorter PR may also be successful [18]. The results related to changes from 0 months to 12 months of PR in clinical outcomes often related to PA were exploratory and not corrected for multiple testing and, therefore, should be interpreted with caution and confirmed in further prospective studies.

Conclusion

The implementation of a semi-automated PA-telecoaching program after a 3 months-PR program was effective to improve the amount of PA. Contrary to our hypothesis, this did not result in a better maintenance of other PR-acquired benefits. Further studies need to look into further strategies to maintain the overall physical fitness

benefits of PR as steps-guided PA-telecoaching may not suffice to achieve this goal.

Abbreviations

ACT	Actigraph
ATS	American Thoracic Society
BMD	Bone Mineral Density
COPD	Chronic Obstructive Pulmonary Disease
CPET	Cardiopulmonary Exercise Testing
CRDQ	Chronic Respiratory Disease Questionnaire
DAM	Dynaport Movemonitor
DEXA	Dual Energy X-ray Absorptiometry
ERS	European Respiratory Society
HDL	High-Density Lipoprotein
IG	Intervention Group
LDL	Low-Density Lipoprotein
MI	Movement Intensity
MID	Minimal Important Difference
mMRC	modified Medical Research Council
MVPA	Moderate to Vigorous Physical Activity
PA	Physical Activity
PR	Pulmonary Rehabilitation
RCT	Randomized Controlled Trial
QF	Quadriceps Force
QoL	Quality of Life
SD	Standard Deviation
STEP	Sustaining Training Effects through Physical activity promotion
UCG	Usual Care Group
V	Visit
WR	Work Rate
6MWD	Six Minutes Walking Distance

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12966-023-01519-w>.

- Additional file 1.** Methods detailed information and Figure AF1 (Algorithm for the calculation of the PA weekly goal in steps/day).
- Additional file 2.** Additional patient characteristics at randomization.
- Additional file 3.** Patient characteristics at the start of pulmonary rehabilitation.
- Additional file 4.** Sensitivity analysis based on complete dataset - Comparison of the changes in PA between intervention and usual care groups.
- Additional file 5.** Changes in additional secondary outcomes between intervention and usual care groups.
- Additional file 6.** Proportion long-term success vs no long-term success in terms of A) functional exercise tolerance, B) symptoms of dyspnea and C) Quality of Life.
- Additional file 7.** Consort checklist.
- Additional file 8.** TIDieR checklist.

Acknowledgements

The authors would like to thank physiotherapists Iris Coosemans, Veronica Barbier, Lode Claes, Ilse Muyaert, Nele Vandenberg and the staff of the Respiratory Rehabilitation Department and Pulmonary Function Department at the University Hospital Leuven for the collection of data and for providing the exercise training program. We are also thankful to Karen Denaux, Kristien de Bent, Dr. Nina Cardinaels, Maarten Spruyt, Sofie Verschuere, Vanessa Van Geel and Willem Dewit for the collection of biological material. The authors would also like to thank the teams from the Respiratory Division (E502) and the Centre for bone densitometry (E415) (UZ Gasthuisberg, Leuven, Belgium) for their assistance with the study assessments.

Authors' contributions

Design of the work: TT, ML and FMR; data acquisition: ML, FMR, HD, AB and SE; data analysis: ML, FMR and HD; drafting the work: ML and FMR. All authors revised this manuscript critically for its intellectual content, gave their final approval of the version to be published and agreed to be accountable for all aspects of the work.

Funding

This work was supported by the Flemish Research Foundation – Flanders (FWO #G.0871.13). FMR was funded by The National Council for Scientific and Technological Development (CNPq), Brazil (249579/2013–8) during the execution of this work. HD is a post-doctoral research fellow of the Flemish Research Foundation (FWO Flanders). AB is a pre-doctoral research fellow of FWO Flanders (1194320 N). WJ is a senior clinical research fellow of FWO-Flanders.

The funder(s) played no role in the design of the study, the collection, analysis, and interpretation of data and in writing the manuscript.

Data Availability

The datasets generated and/or analysed during the current study are not publicly available but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The ethics committee of the University Hospital Leuven approved this study (S57963). All participants gave written informed consent before data collection began.

Consent for publication

Not Applicable.

Competing interests

The authors declare that they have no competing interests.

Received: 20 May 2023 / Accepted: 20 September 2023

Published online: 10 October 2023

References

1. McCarthy B, Casey D, Devane D, Murphy K, Murphy E, Lacasse Y. Pulmonary rehabilitation for chronic obstructive pulmonary disease. *Cochrane Database Syst Rev*. 2015;CD003793.
2. Ries AL, Kaplan RM, Myers R, Prewitt LM. Maintenance after pulmonary rehabilitation in chronic lung disease: a randomized trial. *Am J Respir Crit Care Med*. 2003;167:880–8.
3. Foglio K, Bianchi L, Bruletti G, Battista L, Pagani M, Ambrosino N. Long-term effectiveness of pulmonary rehabilitation in patients with chronic airway obstruction. *Eur Respir J*. 1999;13:125–32.
4. Van Remoortel H, Hornikx M, Demeyer H, Langer D, Burtin C, Decramer M, et al. Daily physical activity in subjects with newly diagnosed COPD. *Thorax*. 2013;68:962–3.
5. Pitta F, Troosters T, Spruit MA, Probst VS, Decramer M, Gosselink R. Characteristics of physical activities in daily life in chronic obstructive pulmonary disease. *Am J Respir Crit Care Med*. 2005;171:972–7.
6. Watz H, Waschki B, Meyer T, Magnussen H. Physical activity in patients with COPD. *Eur Respir J*. 2009;33:262–72.
7. Blondeel A, Demeyer H, Janssens W, Troosters T. The role of physical activity in the context of pulmonary rehabilitation. *COPD J Chronic Obstr Pulm Dis*. 2018;15:632–9.
8. Spruit MA, Singh SJ, Garvey C, Zu Wallack R, Nicl L, Rochester C, et al. An official American Thoracic Society/European Respiratory Society statement: key concepts and advances in pulmonary rehabilitation. *Am J Respir Crit Care Med*. 2013;188.
9. Demeyer H, Louvaris Z, Frei A, Rabinovich RA, De Jong C, Gimeno-Santos E, et al. Physical activity is increased by a 12-week semiautomated telecoaching programme in patients with COPD: a multicentre randomised controlled trial. *Thorax*. 2017;72:415–23.

10. Moy ML, Collins RJ, Martinez CH, Kadri R, Roman P, Holleman RG, et al. An internet-mediated pedometer-based program improves health-related quality-of-life domains and daily step counts in COPD: a randomized controlled trial. *Chest*. 2015;148:128–37.
11. van der Weegen S, Verwey R, Spreeuwenberg M, Tange H, van der Weijden T, de Witte L. It's LiFe! Mobile and web-based monitoring and Feedback Tool embedded in primary care increases physical activity: a Cluster Randomized Controlled Trial. *J Med Internet Res*. 2015;17:e184–4.
12. Burge AT, Cox NS, Abramson MJ, Holland AE. Interventions for promoting physical activity in people with chronic obstructive pulmonary disease (COPD). *Cochrane Database Syst Rev*. 2020:CD012626.
13. Burtin C, Langer D, van Remoortel H, Demeyer H, Gosselink R, Decramer M, et al. Physical activity counselling during Pulmonary Rehabilitation in patients with COPD: a Randomised Controlled Trial. *PLoS ONE*. 2015;10:e0144989–9.
14. Altenburg WA, Ten Hacken NHT, Bossenbroek L, Kerstjens HAM, De Greef MHG, Wempe JB. Short- and long-term effects of a physical activity counselling programme in COPD: a randomized controlled trial. *Respir Med*. 2015;109:112–21.
15. Cruz J, Brooks D, Marques A. Walk2Bactive: a randomised controlled trial of a physical activity-focused behavioural intervention beyond pulmonary rehabilitation in chronic obstructive pulmonary disease. *Chron Respir Dis*. 2016;13:57–66.
16. Nolan CM, Maddocks M, Canavan JL, Jones SE, Delogu V, Kaliaraju D, et al. Pedometer Step count targets during Pulmonary Rehabilitation in Chronic Obstructive Pulmonary Disease. A Randomized Controlled Trial. *Am J Respir Crit Care Med*. 2017;195:1344–52.
17. Armstrong M, Hume E, McNeillie L, Chambers F, Wakenshaw L, Burns G, et al. Behavioural modification interventions alongside pulmonary rehabilitation improve COPD patients' experiences of physical activity. *Respir Med*. 2021;180:106353.
18. Spielmanns M, Gloeckl R, Jarosch I, Leitl D, Schneeberger T, Boeselt T, et al. Using a smartphone application maintains physical activity following pulmonary rehabilitation in patients with COPD: a randomised controlled trial. *Thorax*. 2023;78:442–50.
19. Osadnik CR, Loeckx M, Louvaris Z, Demeyer H, Langer D, Rodrigues FM, et al. The likelihood of improving physical activity after pulmonary rehabilitation is increased in patients with COPD who have better exercise tolerance. *Int J COPD*. 2018;13:3515–27.
20. Pitta F, Troosters T, Probst VS, Langer D, Decramer M, Gosselink R. Are patients with COPD more active after pulmonary rehabilitation? *Chest*. 2008;134:273–80.
21. Loeckx M, Rabinovich RA, Demeyer H, Louvaris Z, Tanner R, Rubio N, et al. Smartphone-based physical activity telecoaching in Chronic Obstructive Pulmonary Disease: mixed-methods study on patient Experiences and Lessons for implementation. *JMIR Mhealth Uhealth*. 2018;6:e200.
22. van Remoortel H, Raste Y, Louvaris Z, Giavedoni S, Burtin C, Langer D, et al. Validity of six activity monitors in chronic obstructive pulmonary disease: a comparison with indirect calorimetry. *PLoS ONE*. 2012;7:1–11.
23. Rabinovich RA, Louvaris Z, Raste Y, Langer D, Van Remoortel H, Giavedoni S, et al. Validity of physical activity monitors during daily life in patients with COPD. *Eur Respir J*. 2013;42:1205–15.
24. Demeyer H, Mohan D, Burtin C, Vaes AW, Heasley M, Bowler RP, et al. Objectively measured physical activity in patients with COPD: recommendations from an International Task Force on Physical Activity. *Chronic Obstr Pulm Dis*. 2021;28:528–50.
25. Guyatt GH, Berman LB, Townsend M, Pugsley SO, Chambers LW. A measure of quality of life for clinical trials in chronic lung disease. *Thorax*. 1987;42:773–8.
26. Demeyer H, Burtin C, Van Remoortel H, Hornikx M, Langer D, Decramer M, et al. Standardizing the analysis of physical activity in patients with COPD following a pulmonary rehabilitation program. *Chest*. 2014;146:318–27.
27. Puhon MA, Lareau SC. Evidence-based outcomes from pulmonary rehabilitation in the chronic obstructive pulmonary disease patient. *Clin Chest Med*. 2014;35:295–301.
28. Gosselink R, Troosters T, Decramer M. Distribution of muscle weakness in patients with stable chronic obstructive pulmonary disease. *J Cardiopulm Rehabil*. 2000;20:353–60.
29. Demeyer H, Burtin C, Hornikx M, Camillo CA, Van Remoortel H, Langer D, et al. The minimal important difference in physical activity in patients with COPD. *PLoS ONE*. 2016;11:e0154587–7.
30. Spruit MA, Pitta F, McAuley E, ZuWallack RL, Nici L. Pulmonary Rehabilitation and physical activity in patients with chronic obstructive Pulmonary Disease. *Am J Respir Crit Care Med*. 2015;192:924–33.
31. Michie S, Richardson M, Johnston M, Abraham C, Francis J, Hardeman W, et al. The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. *Ann Behav Med*. 2013;46:81–95.
32. Mendoza L, Horta P, Espinoza J, Aguilera M, Balmaceda N, Castro A, et al. Pedometers to enhance physical activity in COPD: a randomised controlled trial. *Eur Respir J*. 2015;45:347–54.
33. Hogg L, Grant A, Garrod R, Fiddler H. People with COPD perceive ongoing, structured and socially supportive exercise opportunities to be important for maintaining an active lifestyle following pulmonary rehabilitation: a qualitative study. *J Physiother*. 2012;58:189–95.
34. Geidl W, Carl J, Schuler M, Mino E, Leibert N, Wittmann M, et al. Long-term benefits of adding a pedometer to Pulmonary Rehabilitation for COPD: the Randomized Controlled STAR Trial. *Int J Chron Obstruct Pulmon Dis*. 2021;16:1977–88.
35. Troosters T, Demeyer H, Hornikx M, Camillo CA, Janssens W. Pulmonary Rehabilitation. *Clin Chest Med*. 2014;35:241–9.
36. Michie S, van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement Sci*. 2011;6:42.
37. Ramon MA, Ter Riet G, Carsin AE, Gimeno-Santos E, Agustí A, Antó JM, et al. The dyspnoea-inactivity vicious circle in COPD: development and external validation of a conceptual model. *Eur Respir J*. 2018;52:1800079.
38. Kraus WE, Janz KF, Powell KE, Campbell WW, Jakicic JM, Troiano RP, et al. Daily step counts for measuring physical activity exposure and its relation to Health. *Med Sci Sports Exerc*. 2019;51:1206–12.
39. Tudor-Locke C, Craig CL, Brown WJ, Clemes SA, De Cocker K, Giles-Corti B, et al. How many steps/day are enough? For adults. *Int J Behav Nutr Phys Act*. 2011;8:79.
40. Osadnik CR, Rodrigues FMM, Camillo CA, Loeckx M, Janssens W, Dooms C, et al. Principles of Rehabilitation and Reactivation Respiration. 2015;89:2–11.
41. Balk EM, Earley A, Raman G, Avendano EA, Pittas AG, Remington PL. Combined Diet and Physical Activity Promotion Programs to prevent type 2 diabetes among persons at increased risk: a systematic review for the Community Preventive Services Task Force. *Ann Intern Med*. 2015;163:437–51.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.