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Effect of a Telerehabilitation program in sarcoidosis

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Abstract. *Background:* Sarcoidosis can lead to variable periods of sickness and unemployment. Rehabilitation is recommended in sarcoidosis to improve exercise capacity. Therefore, focus on creating different and flexible rehabilitation options adapted to the needs of working patients is warranted to keep patients with sarcoidosis employed and to reduce the socioeconomic burden. Telerehabilitation (TR) might be an alternative. We investigated the usefulness and effectiveness of TR on exercise capacity in patients with sarcoidosis. *Method:* Single-center, prospective, randomized study including stable patients with sarcoidosis who were enrolled in either a control group where they received the usual standard of care (not including rehabilitation) or in the 3 months TR group composed of video and chat-consultations with a physiotherapist and workout sessions with a virtual autonomous physiotherapist agent (VAPA) (1). 6-minute-walk-test (6MWT), forced vital capacity (FVC), diffusion capacity of the lung for carbon monoxide (DLCO), isometric voluntary contraction (MVC), 7 days pedometry, Saint George Respiratory Questionnaire for interstitial lung disease (SGRQ-I), The King's Brief Interstitial Lung Disease Questionnaire (KBILD) and General Anxiety Disorder-7 Questionnaire (GAD7) were tested before and after 3 months of TR, and after 3- and 6 months follow-up. Patient satisfaction was measured with a 5-point scale (5 very satisfied) and adherence was calculated as percent of tasks and time spent training. Adverse events were documented. *Results:* Thirty patients aged 53.9±13.5 years, male 63.3%, FVC% 88.9±18.8, DLCO% 65.2±16.0, 6MWT 513.1±141.3 were included. Fifteen patients were randomized to TR with VAPA and 15 patients to the control group. Differences in meters walked (6MWTD) between groups was at baseline (-28.9 m (p=0.58)), after 3 (+25.8 m (p=0.57)), 6 (+48.4 m (p=0.39)) and 9 months (+77.3 m (p=0.18)) follow-up in favor of telerehabilitation. No differences were observed in MVC, 7 days pedometry, SGRQ-I, KBILD or GAD7. Exercise adherence in the intervention group was 64% and average exercise time was 28 minutes per exercise session during the first 3 months. Patient satisfaction scored 3.8 ± 0.7. No adverse events were reported. *Conclusion:* VAPA TR did not result in any change in exercise capacity or patient-reported outcomes in this pilot study in patients with sarcoido-

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sis. However, a statistically non-significant trend for improved 6MWTD was observed during follow-up. VAPA TR was safe, had high patient satisfaction and acceptable adherence. Further randomized studies including larger numbers of participants are needed.

Keywords: Sarcoidosis, rehabilitation, telerehabilitation, virtual agents, telemedicine

Background

Sarcoidosis is a multisystem granulomatous disorder of unknown cause affecting different vital organs, especially the lungs (2–4). Sarcoidosis mainly affects younger adults during their prime working and providing years (5,6). Sarcoidosis can lead to reduction of pulmonary function, resulting in cough and dyspnea (3) and can be complicated by fibrosis and pulmonary hypertension. The majority of patients will have a less severe disease course but many may experience fatigue (3). Fatigue and the overall symptoms can result in poor physical conditioning contributing to a vicious cycle of more physical inactivity (7). Physical training in sarcoidosis shows promising evidence of a positive effect on health (8). Improved psychological health and physical functioning (8–10), decreased fatigue (8–10), increased muscle strength (8–10) and increased exercise capacity has been reported (8–10). There is no defined training program with regard to exercise frequency, duration or intensities in sarcoidosis and participation in formal rehabilitation programs may be difficult to combine with work and family life (8,11). Furthermore, long-term effects of pulmonary rehabilitation in sarcoidosis have never been studied and more research is needed (11).

Therefore, there is a need to focus on creating different and flexible rehabilitation options adapted to the needs of patients with sarcoidosis. Also, as sarcoidosis is a relatively rare disease and patients with sarcoidosis are scattered in great geographically areas, it is difficult to organize targeted group training with supervised physical training, convenient for patients. New technologies in healthcare have been increasingly introduced in recent years that enable health care providers to reach and treat patients from a distance. While activity tracking at home may help to motivate people to exercise, supervised training programs or multimodal pulmonary rehabilitation may be more effective (11). Telerehabilitation seems to be a novel approach that can reduce the costs of treatment and reach patients in low inhabited areas (12).

Telerehabilitation for patients with chronic respiratory diseases achieves outcomes similar to traditional hospital-based pulmonary rehabilitation with no safety issues identified (13), however, evidence is limited in pulmonary diseases other than COPD. Drent et al (14) studied the effects of telerehabilitation in sarcoidosis with the use of an electronic activity tracker and online coaching and thus were able to improve exercise capacity and reduce fatigue. In another study, the integration of other data such as heart rate during a Home Monitoring Program is stressed (15). Our aim with the present pilot study is to motivate patients with sarcoidosis to increase their physical activity with the use of telerehabilitation and analyze the effect and usefulness of telerehabilitation on exercise capacity and quality of life in patients with sarcoidosis.

Method

Study design

The study was a single-center, prospective, randomized clinical trial.

The randomization plan was undertaken electronically at randomization.com (www.randomization.com) and subjects were randomized into one block (reproducible using seed 22406).

The Central Denmark Region Committee on Health Research Ethics (reference 1-16-02-621-18) and the Danish Data Protection Agency (reference 633668) approved the study protocol. The trial is registered at clinicaltrial.gov (ID NCT03914027).

Study participants

Stable participants with sarcoidosis were included from the outpatient clinic of Center for Rare Lung Diseases, Department of Respiratory Diseases and Allergy at Aarhus University Hospital in Denmark. Patients were eligible for inclusion if they had a diagnosis of sarcoidosis according to ATS/ERS/JRS/ALAT guidelines based on an assessment using chest x-ray, lung function tests, bronchoscopy and biopsy, if available (2–4, 16). Inclusion criteria were diffusion capacity for carbon monoxide (DLCO) ≥ 30% predicted, forced vital capacity (FVC ≥ 50 predicted, six-minute walk test distance (6MWT) ≥ 150 m, clinically stable in the past six months, and a least 18 years of age. Patients were excluded if they had participated in an official rehabilitation program within four months before start of the study, if they had musculoskeletal disorders or severe cardiac disease (ejection fraction < 30%, daily angina and/or symptomatic valve disorders) which could compromise training had conditions that could hamper the use of TR, or if they were unable to speak and/or understand Danish. All participants provided written informed consent.

Patients were randomized 1:1 to the intervention: a 12-week telerehabilitation program using the VAPA platform (see later) or to a control group receiving usual care without rehabilitation or systematic physical training. End parameters were measured at baseline, after the end of the three-month telerehabilitation period, and at follow-up after three and six months.

Telerehabilitation

Telerehabilitation was delivered using a Virtual Autonomous Physiotherapist Agent (VAPA)(17). VAPA and the telerehabilitation program has previously been described in detail and was originally developed based on interviews with patients with chronic cardiopulmonary diseases (18,19). In short, VAPA is composed of a service platform for therapists to create customized rehabilitation programs, video consultations, e-learning packages, physical exercise programs, online questionnaires, patient digital file and direct chat function in the same tool (1,20). A mobile app that patients can install on a smartphone or tablet is connected directly with a biometric sensor attachable to the patient's chest, arms or fingers to collect data and adjust the rehabilitation program in real time (figure 1) (21). Participants in the intervention group received a kit composed of a smart tablet and a biometric sensor to track pulse during the baseline test, and were taught how to use it at the first visit. The physiotherapist individualized the telerehabilitation program based on baseline 6-minute walk test and a first interview focused on participant daily activity. The physiotherapist programmed VAPA to motivate the participant to physically train at least 60 min a week without pauses between exercises, creating tailored exercise sets divided in 4 different intensity categories combining exercises from 250 aerobic and strength 3D exercises stored in a digital database. Participants received e-learning in short video units followed by multiple choice questions with the goal of teaching them how to cope with their disease symptoms, but also with questionnaires following their experiences and satisfaction performing the different tasks in VAPA. Up to 6 online meetings were scheduled with the participant to follow-up on improvements and to adjust the training program during the first 12 weeks. After this period patients

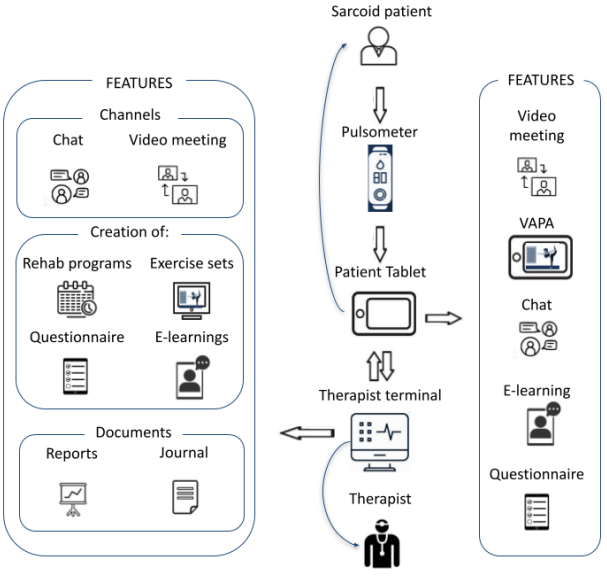

Figure 1. The VAPA platform and its digital and multidimensional environment.
(From Cerdan et al. Tele-Rehabilitation Program in Idiopathic Pulmonary Fibrosis -A Single-Center Randomized Trial used under CC BY (22) / content modified from original.

were offered daily use of VAPA during follow-up but without physiotherapist guidance.

The content of the telerehabilitation program can be found in the supplementary as report 1.

Endpoint parameters

The primary endpoint was exercise capacity measured by 6MWT distance 6MWTD (22) between baseline and the end of three months period of telerehabilitation. Secondary endpoints were 6MWTD from baseline to follow-up after three and six months, 6MWD, % predicted (23), pedometry measured as number of steps walked and total vector magnitude counts per minute score tracked by ActiGraph Monitor wGT3X-BT) for 7 days (24), dyspnea score measured after the 6MWT with the modified 0-10 Borg scale (25), muscle strength measured with the maximal isometric voluntary contraction (MVC) (26), quality of life measured by the IPF-specific version of St. George's Respiratory Questionnaire (SGRQ-I) (27), King's Brief Interstitial Lung disease (K-BILD)(28) and the General Anxiety Disorder Score (GAD7) (29). Pulmonary function was recorded by forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1) and diffusion capacity for carbon monoxide (DLCO). Patients in the intervention group were asked to rate their satisfaction with VAPA by answering a question using a 5-point scale (1: "very unsatisfied" to 5: "very satisfied") after each training session. The actual tasks performed as well as training time as the average training time/week were registered automatically by VAPA and compared to the values planned for the individual patient.

Statistics

There are no previous studies of telerehabilitation in sarcoidosis but a previous study of pulmonary rehabilitation in sarcoidosis measured a significant and positive difference in 6MWTD. Karadall et al. (30) document in their study a 6MWD of 554.2 ± 59.8 m at baseline and an improvement in the intervention group of +65.7 m. Using the results from Karadall et al, and with a power of 0.8 and with a 0.05 significance, we included 26 patients, divided into two groups with 13 in each group (31). A moderate 15% drop-out percentage was expected and thus 30 patients were recruited.

Results from parametric data are expressed as means ± standard error, and non-parametric data are expressed as medians with interquartile ranges. Changes in endpoints from baseline to after telerehabilitation and follow-up, respectively, were compared between groups using the unpaired t-test for parametric data and the rank sum test for non-parametric data using 95% confidence intervals. Changes in variables from baseline to after telerehabilitation and follow-up, respectively, were analyzed within groups using the paired t-test for parametric data and the Wilcoxon signed rank test for non-parametric data.

Statistical analyses were conducted according to the intention-to-treat principle (32).

Results

Patients

Thirty patients with sarcoidosis were included. Fifteen patients were randomized to telerehabilitation with VAPA and 15 patients to the control group. Mean age was 51.6 ± 12.7 and 56.1 ± 14.4 in the VAPA group and control group, respectively. Baseline characteristics showed numerical more males with a longer disease duration before inclusion and higher number of ever-smokers in the intervention group; baseline parameters were not statistically significant between the two groups. Baseline demographics are displayed in Table 2.

Eighty-three patients were screened for eligibility; seventeen patients declined participation and thirty-six met the exclusion criteria; thus, thirty patients were randomized and included. Ten patients (66.6%) in the VAPA group and twelve (80%) in the control group completed the 12-week study period. Nine patients (60%) in the VAPA group and 11 (73.3%) in the control group completed all follow-up visits. Patient disposition is shown in figure 2.

Baseline demographics in eligible patients declining participation were not different from participants (Table 1, Report 2 supplementary).

Table 2. Baseline demographics of the 30 patients included in the study

Variable		Control n=15	TR with VAPA n=15	p
Male, n (%)		9 (60%)	10 (66%)	
Age (years), mean (SD)		51.6 (12.70)	56.1 (14.4)	0.37
	♂	49.67 (13.83)	53.6 (14)	0.55
	♀	65.83(9.37)	47.6(9.76)	*0.01*
Weight (kg), mean (SD)		81.93 (16.63)	93.87 (22.09)	0.35
	♂	88.80 (14.98)	91.36 (12.23)	0.69
	♀	71.62 (14.23)	78.88 (12.94)	0.4
Height (cm) mean (SD)		173.30 (12.41)	174.57 (6.93)	0.73
	♂	181.33 (6.10)	178.05 (5.37)	0.23
	♀	161.25 (9.00)	167.6 (3.51)	0.17
BMI mean (height2/weight) (SD)		27.27 (4.86)	28.68 (4.53)	0.42
	♂	26.91(3.68)	28.90(4.28)	0.3
	♀	27.8(6.63)	28.23(5.49)	0.91
6MWTD (m), mean (SD)		527.53 (163.48)	498.67 (119.07)	0.58
	♂	587(135.83)	498.50(146.56)	0.20
	♀	438.33(171.46)	499.00(35.95)	0.46
6MWTD% predicted (m), mean (SD)		90.50(21.32)	84,65(17.84)	0.42
	♂	89.2(16.8)	82.27(20.33)	0.43
	♀	92.46(28.53)	89.42(11.93)	0.83
Dyspnea by Borg Scale mean (SD)		5.87 (2.56)	6.67 (2.32)	0.38
MVC arm & leg total mean (SD)		16.4(4.6)	16.3(5.0)	0.93
7 days pedometry mean (SD)		14282.80 (7515.58)	17935.15 (11072.10)	0.86
FVC (% predicted), mean (SD)		84.73 (17.93)	93.13 (19.38)	0.13
FEV1 (% predicted), mean (SD)		63.00 (23.94)	79.33 (16.36)	*0.04*
FEV1/FVC (% predicted), mean (SD)		75.87 (21.43)	87.07 (14.34)	0.10
DLCO (% predicted), mean (SD)		64.30 (17.18)	65.87 (15.91)	0.82
SGRQ-I total mean (SD)		31.03 (21.69)	39.08 (22.02)	0.32
KBILD total mean (SD)		62.00(9.77)	59.13(11.82)	0.47
GAD7 mean (SD)		1.73 (3.11)	4.20 (5.65)	0.15
Scadding stage (radiological stadium)	0	2	5	
	1	1	2	
	2	2	2	
	3	3	0	
	4	5	6	
Medical treatment				
Corticosteroid		5	8	
Immunomodulatory		4	4	
Smoking status				
Current, n		1	0	
Former, n		3	5	
Never, n		11	10	

Table 2. Baseline demographics of the 30 patients included in the study

Variable	Control n=15	TR with VAPA n=15	p
Symptoms			
Dyspnea	11	15	
Fatigue	2	5	
Weight loss	1		
Cough	6	6	
Arthralgia	4	5	
Uveitis	1		
Hypercalcemia		1	
Erythema nodosum		1	
Other affected organs			
No extrapulmonary organ involvement	4	7	
Skin	2	1	
Liver	1	2	
Spleen	1	1	
Joint	4	4	
Eye	1		
Heart		1	
Kidneys		1	
Uterus	1		

SD: Standard deviation; FVC: Forced vital capacity; FVE1: Forced Expiratory Volume in the first second; DLCO: Diffusion capacity for carbon monoxide; 6MWTD: 6 minute walk test distance; m: meter; Dyspnea: 0-10 Borg scale after 6MWT; MVC arm & leg total: maximal isometric voluntary contraction in arm and leg ;7 days pedometry: steps walked in 7 days; SGRQ: Saint George Respiratory Questionnaire; KBILD: King's Brief Interstitial Lung Disease Questionnaire; GAD7: General Anxiety Disorder-7 Questionnaire.

Endpoints

In patients randomized to telerehabilitation with VAPA, we found a 6MWTD of 567.30±103.60 after telerehabilitation (three months); 576.67±113.71 at six months and 575.44±139.44 at nine-months, while controls experienced a decline from 546.46±140.95 m at baseline to 541.54±108.64 m, 528.27±129.04 m and 498.10±99.99 m at three-, six- and at nine-months follow-up, respectively (Figure 3).

No statistically significant differences between groups were found after rehabilitation at 3 months (+24.42 m (p=0.3)), at 6 months follow-up (+48.5 m (p=0.2)) or at 9 months (+77.34 m (p=0.18) follow-up.

Four patients with Scadding stage 0 were included by mistake due to late diagnosis updates discovered after the end of enrollment period, data cleaning and statistics were performed. All four patients had previously shown Scadding stage 1-2 on their chest radiogram, had extrapulmonary sarcoidosis involvement and were treated with both prednisolone and methotrexate. We excluded their data to analyze the results of the 6MWTD variable and no significant differences were found (Analysis is shown in supplementary report 6).

No statistically significant differences between groups were observed regarding exercise activity as measured by pedometry, QoL and PFT (Table 3).

Continued use of VAPA

Seven patients (47%) decided to continue training with telerehabilitation after the first 3 months of which two (13%) decided to continue training after 6 months. Additional results can be found in the Supplemental Digital Content file.

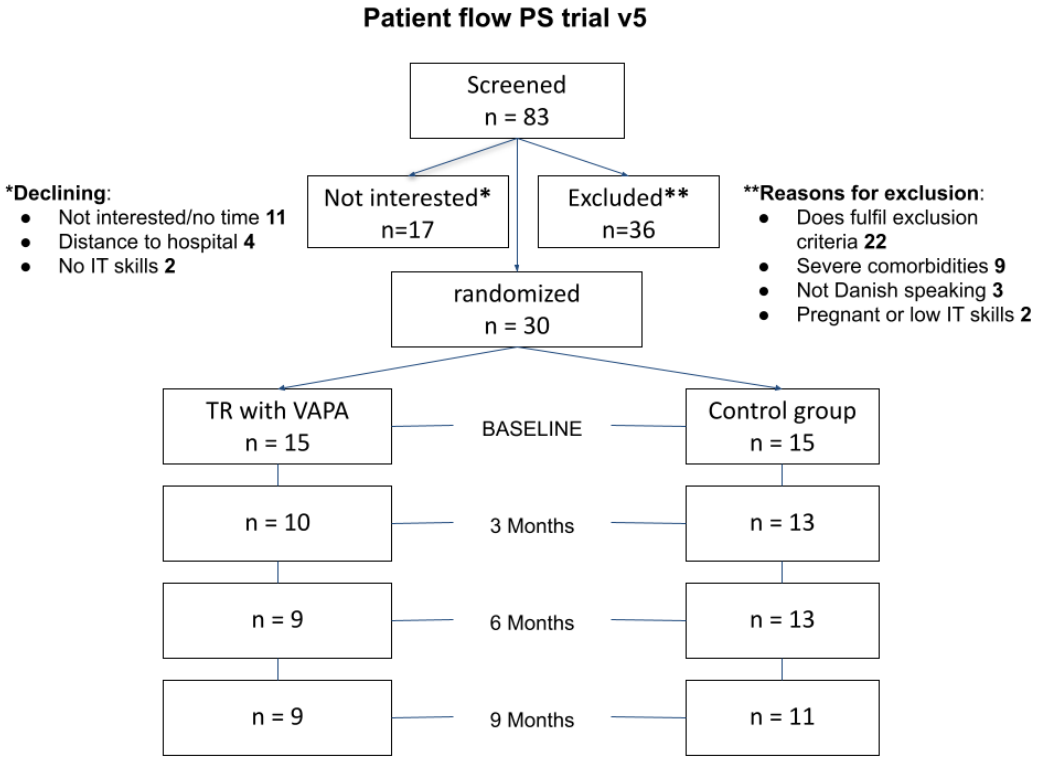

Figure 2. Enrollment and randomization in the overall population.

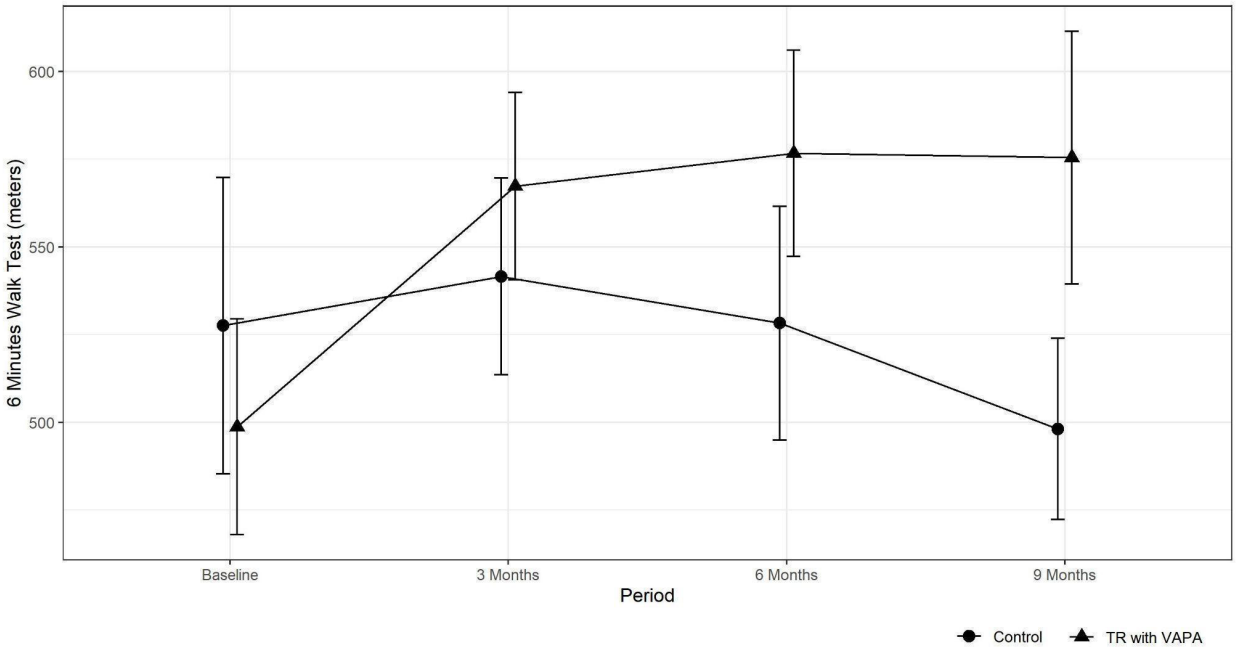

Figure 3: 6-minute walk test distance (6MWTD) in the intervention group and the control group displayed as the mean difference in meters walked (mean ± standard deviations).

Table 3: Changes in primary and secondary endpoints within groups over time.

Variable	Baseline			Three months		
	VAPA	Control	(Δ	VAPA	Control	(Δ
6MWTD	498.7 ± 119.1	527.5 ± 163.5	28.9 (25.8)	567.3 ± 103.6	541.5 ± 108.6	-25.8 (21.9)
Dyspnea by Borg Scale	6.7 ± 2.3	5.9 ± 2.6	-0.8 (0.4)	7.0 ± 2.4	5.8 ± 2.5	-1.2 (0.5)
MVC arm & leg total	16.2 ± 5.0	16.4 ± 4.6	0.2 (0.9)	13.4 ± 8.9	18.4 ± 5.2	5.0 (1.5)
7 days pedometer	17935 ± 11072	14282 ± 7515	-3652 (1764)	16780 ± 5100	14245 ± 6552	-2535 (1351)
SGRQ-I	39.1±22.0	31.0±21.7	8.05 (7.98)	31.9± 23.2†	28.69 ± 20.23	3.22 (8.90)
K-BILD	59.2 ± 11.9	62.1 ± 9.7	2.8 (2.0)	68.9 ± 14.2	66.6 ± 11.9	-2.3 (2.6)
GAD7	4.2 ± 5.6	1.7 ± 3.1	-2.5 (0.8)	2.7 ± 3.1	2.8 ± 5.2	0.1 (0.9)
Variable	Six months			Nine months		
	VAPA	Control	(Δ	VAPA	Control	(Δ
6MWTD	576.7 ± 113.7	528.3 ± 129.0	-48.4 (27.2)	575.4 ± 139.4	498.1 ± 100.0	-77.3 (28.3)
Dyspnea by Borg Scale	7.6 ± 2.1	6.0 ± 2.8	-1.6 (0.6)	6.9 ± 2.1	6.9 ± 2.1	0.0 (0.5)
MVC arm & leg total	18.2 ± 5.4	17.4 ± 4.3	-0.9 (1.1)	19.3 ± 7.3	16.5 ± 4.8	-2.8 (1.4)
7 days pedometer	14591± 4951	15978 ± 8428	1386 (1571)	16609 ± 8454	13094 ± 7435	-3514 (1895)
SGRQ-I	28.1±22.5	31.7 ± 20.3	-3.60 (9.58)	25.4±17.9	32.6±21.1	-4.50 (7.87)
K-BILD	65.0 ± 15.3	65.4 ± 13.1	0.4 (3.1)	67.4 ± 11.1	68.0 ± 15.6	0.6 (3.0)
GAD7	1.7 ± 2.0	3.5 ± 5.8	1.9 (1.0)	0.6 ± 0.7	2.1 ± 2.6	1.5 (0.5)

*Data are shown as mean ± SD or (Δ· difference (standard error). * Change from baseline significantly different from placebo group ($p < 0.05$); † $p < 0.05$ compared to baseline value within group; 6MWTD: 6-minute walk test; Dyspnea: 0-10 Borg scale after 6MWT; MVC arm & leg total: maximal isometric voluntary contraction in arm and leg (kilogram-force (kgf)); SGRQ-I: Saint George Respiratory Questionnaire; KBILD: The King's Brief Interstitial Lung Disease Questionnaire; GAD7: General Anxiety Disorder-7 Questionnaire.*

Adherence and Patient´s Satisfaction

Adherence to exercise for the patients in the telerehabilitation with VAPA group decreased over time (Figure 4). During the first three months, 15 patients had an adherence of 64% with an average of 28 minutes of exercise per session. Between 3-6 months, seven patients decided to continue training on their own with an adherence of 27%, and trained on average 26 minutes per session. Two patients decided to continue training between 6-9 months with an adherence of 48%, and trained 21.8 minutes per session. A total of 264 responses on the Likert satisfaction score (1-5) resulted in an average score of 3.8 ± 0.7.

Additional results

Results regarding the program for telerehabilitation, participants non-participants, baseline data, follow up data, protocol for maximal isometric voluntary contraction in arm and leg and 6-minute walk test distance results occluding the 4 patients with Scadding stage 0 can be found in the Supplementary reports 1-6.

Discussion

This study is the first to evaluate the effects of a new telerehabilitation platform, VAPA, in patients with sarcoidosis as an alternative to standard care. VAPA telerehabilitation did not show significantly sustained exercise capacity in sarcoidosis. Patient satisfaction with VAPA telerehabilitation was high although patient adherence decreased over time.

Exercise Capacity

According to Karadall et al., rehabilitation in the intervention group of patients with sarcoidosis resulted in a significantly improved exercise capacity (+65.7 m, p=0.01) after 6 weeks of inspiratory muscle train-

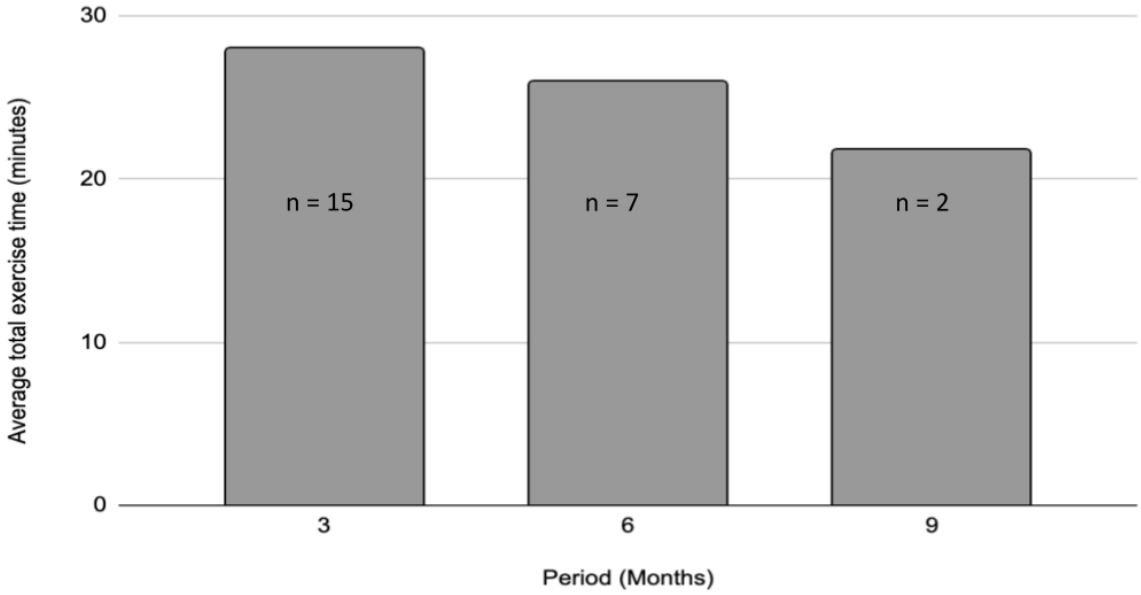

Figure 4. Average time per exercise session by patients for each 3-month period.

ing (30). We found a statistically non-significant mean improvement of +68.63 m by the 6MWT with TR. Even though we could not show statistically significant improvements and our rehabilitation period was longer than 6 weeks, our results with the telerehabilitation with VAPA are similar to Karadall et al.(30). Compared to the control group, telerehabilitation with VAPA resulted in a numerical although not statistically significant improvement of 25.8 m, which is below the minimum clinically important difference for 6MWTD for parenchymal lung diseases (30–33 m) (33). Guber et al. (34) found that patients with sarcoidosis enrolled in a pulmonary rehabilitation trial with obstructive lung disease (FEV1/FVC <70%) showed greater improvement in 6MWD with pulmonary rehabilitation. In our study, baseline FEV1/FVC% was above 70% for 80% of all participants in the study and for 93% for all the participants in TR with VAPA (Table 3 and Report 3 in supplementary) which might partly explain the lack of significant improvement.

The lack of significant improvement might also be due to the fact that telerehabilitation with VAPA did not include specific inspiratory muscle training exercises but was more focused on aerobic and anaerobic exercises. Another reason could be insufficient training time as the minimum expected weekly training was only 60 minutes while in another successful recent study, 90 minutes of training per week was used (35). Also, Karadall et al. included younger patients (mean age 45.1±8.1 years), more females 66.7%, less overweight patients (BMI 27.0 ± 5.1) and all patients had Scadding stage III -IV(30) compared to study participants in our study. Thus, the patients in the intervention group by Karadall et al. had a higher chance of reaching a training benefit advantage, compared to our patients with sarcoidosis.

A recent study on sarcoidosis rehabilitation included only patients with Scadding stage IV chest x-ray. In this study, patients trained 90 minutes/week during 2 months with supervised endurance-, group based- and individual strengthening exercises training demonstrating an improvement in exercise tolerance using the 6-min stepper test after pulmonary rehabilitation (+66, p 0.012) at 6- (+155, p 0.001) and 12 month (+113, p 0.001) follow up (35). We found similar trends for improvements but no significant difference between groups, potentially due to the fact we included patients with less severe pulmonary involvement.

Even if we excluded the 4 patients in Scadding stage 0 from the analysis of the primary endpoint,

(6MWTD) the results showed no significant difference between groups in 6MWTD (supplementary report 6).

Pedometry

Wallaert et al. was unable to demonstrate a beneficial effect of rehabilitation on daily life physical activity measured by an armband in pulmonary sarcoidosis patients (35), similar to our findings based on 7 days pedometry. At the same time, Wallaert et al. and our intervention group experienced a similar decrease in participants' physical activity score during follow up. We agree with Wallaert et al. that to improve daily life physical activity in pulmonary sarcoidosis, long-term behavioral programs are potentially needed to complement pulmonary rehabilitation.

As experienced in our study and also aby Wallaert et al., it seems that patients who dedicate time to train physically to reduce their disease symptoms have less surplus to increase their daily life physical activity. The question is, if patients that intentionally participate in physical rehabilitation programs find that their participation in the rehabilitation program is enough to cope with their symptoms or if it is because the rehabilitation program increases their fatigue resulting in fewer resources to stay active?

Froidure et al. found by the use of via daily pedometry that patients with sarcoidosis appeared to have reduced physical activity of daily life compared to healthy people (36). Froidure only included patients with Scadding stage IV sarcoidosis. We observed a similar decrease in 7 days pedometry after 3 months and at the follow-up visits in our cohort of sarcoid patients that included patients with different Scadding stages (stage 0-IV) (Figure 4 and Report 4 in the supplementary).

Quality of Life

Aerobic exercise, respiratory muscle training, oxygen therapy, nutritional intervention, education, and self-management approaches are all used in hospital-based pulmonary rehabilitation programs. In VAPA, we attempted to digitalize as much of the rehabilitation program's content as possible in order to improve patients' quality of life. The content was expected to empower the patient and improve their quality of life by combining aerobic exercise and respiratory muscle training, nutritional intervention, education, and self-management approaches by creating e-learning packages with direct messages and "know-how" on how to cope with disease symptoms. We were not able to show improved quality of life in accordance with Wallaert et al. (35).

Telerehabilitation

Long-term behavioral programs are potentially needed to complement rehabilitation programs. Telerehabilitation could be a potential solution to accomplish such a goal if the training time was increased to at least 90 minutes per week and inspiratory muscle training exercises with individual endurance and strengthening exercises were included. We found a decrease of adherence over time similar to a previous study and specific efforts are probably needed to prevent this (35).

One strategy could be to involve a real physiotherapist online also after the three first months of telerehabilitation.

Limitations and Strengths

Our study has some limitations. The low number of participants, few of them with mild disease and the drop-out rate may have influenced the results. The dropout rate, however, is comparable to that of patients in rehabilitation programs for other chronic respiratory diseases (37,38). In terms of our pedometer measurements, it's also important to note that we had a small number of patients and that they were included in the study at different times of the year. For example, a patient who was enrolled in the summer may have walked less during follow-up in the winter, which could explain the large standard deviation in our results. The randomized design and the long-term follow-up are also an advantage in our study. More research is needed to discover the best exercise training for patients with sarcoidosis and to identify techniques to optimize long-term benefits.

Conclusion

No significantly beneficial effect of telerehabilitation with VAPA in patients with sarcoidosis was demonstrated. Exercise capacity at 3-, 6- and 9-month follow-up improved numerically but was statistically non-significant while decreasing exercise capacity was observed in the control group. No change in QoL, MVC or 7 days pedometry was observed. VAPA telerehabilitation was safe, had high patient satisfaction and acceptable adherence. Further randomized studies with a larger cohort and more severe disease involvement are needed to study the differences between telerehabilitation vs conventional treatment in sarcoidosis.

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Conflicts of interest: J. Cerdán-de-las-Heras is PhD student at Aarhus University Hospital, as well as a founder of Physio R&D limited company, who has designed and developed the Virtual Autonomous Physiotherapist Agent. The rest of the authors declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

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