Home monitoring of lung function, symptoms and quality of life after admission with COVID-19 infection: The HOMECOMIN’ study

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Abstract

Background and objective: To develop targeted and efficient follow-up programmes for patients hospitalized with coronavirus disease 2019 (COVID-19), structured and detailed insights in recovery trajectory are required. We aimed to gain detailed insights in long-term recovery after COVID-19 infection, using an online home monitoring programme including home spirometry. Moreover, we evaluated patient experiences with the home monitoring programme.

Methods: In this prospective multicentre study, we included adults hospitalized due to COVID-19 with radiological abnormalities. For 6 months after discharge, patients collected weekly home spirometry and pulse oximetry measurements, and reported visual analogue scales on cough, dyspnoea and fatigue. Patients completed the fatigue assessment scale (FAS), global rating of change (GRC), EuroQol-5D-5L (EQ-5D-5L) and online tool for the assessment of burden of COVID-19 (ABCoV tool). Mixed models were used to analyse the results.

Results: A total of 133 patients were included in this study (70.1% male, mean age 60 years [SD 10.54]). Patients had a mean baseline forced vital capacity of 3.25 L (95% CI: 2.99–3.44 L), which increased linearly in 6 months with 19.1% (Δ0.62 L, p < 0.005). Patients reported substantial fatigue with no improvement over time. Nevertheless, health status improved significantly. After 6 months, patients scored their general well-being almost similar as before COVID-19. Overall, patients considered home spirometry useful and not burdensome.

Conclusion: Six months after hospital admission for COVID-19, patients’ lung function and quality of life were still improving, although fatigue persisted. Home monitoring enables detailed follow-up for patients with COVID-19 at low burden for patients and for the healthcare system.

Keywords
chronic lung disease, coronavirus disease, COVID-19, eHealth, health-related quality of life, home spirometry, patient-reported outcome measures, telemedicine

This study was previously presented at the 2021 Annual Congress of the European Respiratory Society (ERS).

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INTRODUCTION

With more than 424 million cases and almost 6.4 million deaths worldwide in February 2022, the coronavirus disease 2019 (COVID-19) pandemic has enormous impact on worldwide healthcare systems.\(^1\) Hospitalization rates are estimated to be around 5\(^\circ\) in patients with COVID-19.\(^2,3\) Not only hospital admissions have impacted our healthcare systems, but also the aftercare and follow-up of COVID-19 patients after discharge.

The long-term effects of COVID-19 have been described in different studies. Months after COVID-19 infection, many patients still have lung function impairment and experience fatigue, muscle weakness, joint pain and psychological problems, with significant impact on quality of life.\(^4,5\) Although the total number of patients with post-COVID-19 sequelae is large and continues to expand, there is no consensus on follow-up schedules after hospitalization. Different follow-up strategies have been proposed\(^7,9\); however, the optimal frequency of hospital visits and best time points for lung function testing and imaging still need to be determined. To develop targeted and efficient follow-up programmes, more structured and detailed insights in recovery trajectory of patients are required.

Together with patients, we developed an online home monitoring programme for interstitial lung diseases (ILD), including home spirometry and patient-reported outcome measures (PROMs). This online home monitoring programme has shown to be feasible, reliable and much appreciated by patients.\(^10-13\) It facilitates detailed insights in disease course at low burden for patients and healthcare providers, and continuity of care during the COVID-19 pandemic.\(^14\) We modified this existing online home monitoring programme into a version for patients with COVID-19 that could be used for home-based follow-up after hospital discharge.

In this study, we aimed to gain more detailed insights in long-term recovery after COVID-19, using an online home monitoring programme. Moreover, we evaluated patient experiences with the home monitoring programme.

METHODS

Study design and participants

This is an ongoing observational, multicentre study conducted at three hospitals in the Netherlands. Adults (≥18 years) were eligible for participation if they had PCR-proven COVID-19 and parenchymal abnormalities on imaging during hospital admission. Patients without internet access were excluded. Patients were either included at discharge, or during their first regular outpatient clinic visit 6 weeks after discharge. Patients were followed up for at least 6 months after discharge.

Study procedures

Data were collected via the Conformité Européenne (CE)-certified HOMECOMIN’ application (Curavista©; The Netherlands). We have adapted the HOMECOMIN’ application from a previous version of the application for ILD.\(^13\) Patients have real-time access to their own data. Data are directly sent to the healthcare team through the application. The application includes home spirometry, using a validated Bluetooth-enabled home spirometer (Spirobank Smart, MIR®, Italy). Patients were asked to perform daily home spirometry (forced vital capacity, FVC) during the first 2 weeks after hospital admission and weekly home spirometry (three consecutive measurements a day at approximately the same time) thereafter. The highest of these three values was used for further analysis. In addition, patients reported weekly pulse oximetry results and completed visual analogue scales (VAS) on cough, fatigue and dyspnoea via the application. Different health-related quality of life and other PROMs were collected at discharge, 6 weeks, 3 months and after 6 months. Included questionnaires were the EuroQol five dimensions 5-level questionnaire (EQ-5D-5L),\(^15\) the fatigue assessment scale (FAS)\(^16\) the global rating of change (GRoC)\(^17\) and the online tool for the assessment of the burden of COVID-19 (ABCov tool).\(^18\) All results are visualized in graphs and directly available for patients and healthcare team (Figure 1 and Figure S2 in the Supporting Information).

VAS scores ranged from 0 to 10, with a higher score indicating more severe symptoms. The EQ-5D-5L consists of five questions on a 5-point Likert scale and a VAS on general health status with scores from 0 to 100. Higher scores indicate better health status. The FAS is a 10-item self-administered questionnaire about fatigue. The score ranges from 5 to 50 points, with a score of ≥22 points as cut-off for fatigue. The GRoC scale is a 1-item questionnaire in which patients describe their current well-being compared to a previous moment on a Likert scale from −7 (a very great deal worse) to 7 (a very great deal better). The ABCov tool is created to monitor COVID-19 patients over time. The tool has been adapted from the assessment of burden of chronic obstructive pulmonary disease (ABC) tool, which is used for patients with chronic obstructive pulmonary disease (COPD).\(^19\) The questionnaire consists of several domains, such as functional status, mental status, emotions and fatigue, BMI, smoking status and different symptoms. A 7-point Likert scale was used for all domains other than the risk factors. Higher score on the Likert scale
**FIGURE 1** Visualization of the online tool for the assessment of the burden of COVID-19 (ABCoV tool) over time. Green balloons indicate a satisfactory score, orange balloons an intermediate score and red balloons a low score. Grey balloons represent the location of the previous balloons. (A) ABCoV tool assessed at baseline. (B) ABCoV tool assessed at 3 months. (C) ABCoV tool assessed at 6 months.
For our models, we investigated the residuals to evaluate the assumptions of the models. All data were analysed using SPSS version 25.0.0.1. (IBM) and R (version 4.1.0). We used package nlme for the mixed models, GLMMadaptive for the hurdle models and DHARMA package for the residuals of the hurdle models.

RESULTS

A total of 133 patients were included between May 2020 and February 2021. Sixteen patients withdrew before the start of the study, and their data were excluded from analysis. 70.1% of the patients were male, and the mean age was 60 years (SD 10.5). Median time between diagnosis and admission was 0 days (IQR: 0–5). Forty-nine patients had been admitted to the intensive care unit (ICU) for mechanical ventilation; median duration of mechanical ventilation was 18 days (IQR: 9–30). Median duration of hospital admission in the overall cohort was 13 days (IQR: 5–31), and in the cohort admitted to the ICU 36 days (IQR: 20–53). Baseline characteristics are described in Table 1.

**Spirometry, pulse oximetry and imaging**

One hundred and one patients (86%) performed home spirometry. Patients had a mean baseline FVC of 3.25 L (95% CI: 2.99–3.44 L). During 6 months after hospitalization, FVC increased significantly with 19.1% (Δ + 0.62 L, p < 0.005). At 6 months, lung function was still linearly increasing (Figure 2). An example of home spirometry values over time in an individual patient is presented in Figure S2 in the Supporting Information. Adherence to weekly spirometry decreased over time, with 86.1% of patients performing weekly home spirometry after 3 months, and 74.2% after 6 months. Ninety patients (77%) performed in-hospital lung function measurements 3 months after discharge. Mean FVC was 3.86 L (SD 1.12) or 91.16% of predicted (SD 16.37). Mean forced expiratory volume in 1 s (FEV1) was 2.97 L (SD 0.92) or 91.16% of predicted (SD 16.98). Mean FEV1/FVC ratio was 0.78 (SD 0.15). Mean DLCO was 78.20% (SD 18.11). Of all patients, 74.4% had an FVC above the LLN. 58.6% of the patients had an FEV1 above the LLN and 82.2% of the patients had an FEV1/FVC ratio above the LLN. 58.6% (n = 87) had a DLCO above the LLN. Correlation between home spirometry and in-hospital measurements at 3 months was very strong (r = 0.93, p < 0.001). One hundred and five patients collected pulse oximetry data; mean baseline value was 96.1% (95% CI: 95.72–96.49). There was a small significant but clinically irrelevant increase of 0.4% over a period of 6 months (p < 0.005). At 3 months, 67.4% of patients had an abnormal computed tomography scan, mostly showing traction bronchiectasis and/or bronchiolectasis (38.2%), ground-glass opacifications (38.2%), fine reticulations (22.5%), consolidation (13.5%) and air trapping (6.7%).
Estimated cough score, as modelled by the hurdle model, directly after hospital admission was 1.03 (95% CI: 0.88–1.21), with no significant difference over time (Δ + 0.13, p = 0.56). Baseline dyspnoea score was 3.61 (95% CI: 2.69–4.84) and did not change over time (Δ/Co 0.80, p = 0.32). Patients had a baseline VAS fatigue score of 5.29 (95% CI: 4.34–6.45), with no improvement in 6 months (Δ/Co 0.87, p = 0.31). Similar to the results of the VAS fatigue, the FAS showed a high baseline score of 23.23 (95% CI: 20.93–25.33), with stable fatigue over time (Δ + 2.21, p = 0.36). The mean baseline EQ-5D-5L utility score was 0.71 (95% CI: 0.65–0.74) and improved significantly during the study (Δ + 0.12, p < 0.001). Baseline GRoC score was 3.52 (95% CI: 4.48 to 2.86). Scores improved significantly to a mean of 0.23 (Δ + 3.39, p < 0.001) after 6 months, indicating that patients scored their general well-being almost the same as before COVID-19. Results are visualized in Figure 3. The mean baseline score of the CCQ was 1.89 (95% CI: 1.72–2.15) and showed a significant improvement over time (Δ/Co 1.00, p < 0.001). An overview of other domains of the ABCoV tool over time is shown in Figure S1 in the Supporting Information.

### Patient experiences

Fifty-nine patients (50%) completed the questionnaire on experiences and satisfaction with the home monitoring programme. More than three-quarters (76.3%) would recommend the home monitoring programme to others, and 59.3% would like to continue using the app. The remaining patients stated that home monitoring was no longer needed as they felt fully recovered. 76.3% of patients answered that home spirometry provided more insights in their recovery trajectory. In general, patients considered home spirometry useful, pleasant and not burdensome (Figure 4).

### DISCUSSION

In this study, we found that pulmonary function linearly increased during the first 6 months after hospital admission for COVID-19. Six months after discharge, FVC was still improving and had not reached a plateau, indicating that lung function is expected to further improve over time. However, symptoms such as fatigue and mild dyspnoea

### TABLE 1 (Continued)

| Tocilizumab | 1 | 0.9% |
| Delirium | 35 | 29.9% |
| Thromboembolic events | 28 | 23.9% |

Abbreviations: COPD, chronic obstructive pulmonary disease; COVID-19, coronavirus disease 2019; ICU, intensive care unit; IQR, interquartile range.
In this study, we evaluated the finding that 77% of patients had a pulmonary fibrosis in a subset of patients after severe acute respiratory distress syndrome coronavirus in 2003 and the higher percentage of patients with impaired DLCO could also be partly due to pulmonary vascular abnormalities and should be monitored for a longer period of time. Compared with previous studies, we were able to describe a more granular overview of lung function recovery over time, because of the frequent home spirometry measurements.

Early in the pandemic, one of the most feared complications of COVID-19 was development of pulmonary fibrosis with progressive lung function impairment. Reasons for this were similarities in the pathophysiology of acute respiratory distress syndrome and pulmonary fibrosis, and development of pulmonary fibrosis in a subset of patients after severe acute respiratory distress syndrome coronavirus in 2003 and the Middle East respiratory syndrome coronavirus infection. Therefore, studies on the use of anti-fibrotic medication in patients with post COVID-fibrosis are currently ongoing (NCT04856111, NCT04282902, NCT04541680, NCT04607928 and NCT04619680). Mean increase in FVC in our population was 19.1%. Therefore, although there may be a mechanistic rationale for the use of anti-fibrotic medication post-COVID, our data suggest that the target population for the use of anti-fibrotic medication post-COVID-19 will be limited.

Our study confirmed that a majority of patients have remaining symptoms after COVID-19 infection, with fatigue being the most reported symptom. Although lung function generally improved, mild complaints of dyspnoea persisted in many patients, which could possibly be due to deconditioning. Nevertheless, general well-being measured with the GroC scale indicated that patients returned to prior health, and health status measured with the EQ-5D-5L after 6 months was comparable to the Dutch norm population > 60 years.

Several home monitoring programmes have been developed for patients with COVID-19, which aimed at early detection of disease deterioration for non-hospitalized patients, or facilitating earlier discharge by monitoring oxygen saturation at home. In this study, we evaluated the use of an online home monitoring programme for patients recovering from severe COVID-19. We found a strong correlation between in-hospital measurements and home monitoring measurements, which is in line with previous studies. Our home monitoring programme focuses on long-term monitoring and empowerment of patients after hospitalization. This can be especially useful for personalized follow-up and treatment of patients with long COVID. The patients can see a visual overview of their results, helping them gain detailed insights in disease course and become more confident with regard to their recovery process. Home monitoring could not only replace hospital visits, but also make hospital visits more structured and efficient. Replacement of hospital visits by home monitoring will probably also lead to reduction in healthcare costs and help lowering the burden on our healthcare system. We found that most patients were positive towards home monitoring, comparable with previous experiences in patients with ILD. Moreover, this study confirmed that online home monitoring is feasible in elderly patients. Nevertheless, adherence to home spirometry decreased over time. Patients stated that home monitoring was useful as it provided better insights in their recovery process, but had no added value after they felt fully recovered. Thus, in patients with a fast recovery trajectory, the additive value of home monitoring is likely limited.

We believe that home monitoring can be used to gain better insights in the recovery trajectory of the individual patient, and provide personalized care after hospital admission. In-hospital follow-up could be discontinued earlier, guided by home monitoring results. In addition, home monitoring has the potential to identify the small group of patients with abnormal recovery trajectories or who may develop progressive pulmonary fibrosis. For patients with persisting symptoms, the home monitoring tool can also facilitate home-based interventions, such as pulmonary rehabilitation. The current study shows the feasibility of home monitoring in this patient group, but future studies should further confirm the hypotheses regarding potential benefits.

The strengths of this study are its prospective multicentre design, and the inclusion of patients during both first and second COVID-19 waves. This study also had some limitations. Many patients were not able to participate at the time of discharge from the hospital as they were still too weak. Patients were often transferred from the hospital to a rehabilitation centre before they could return to their homes. We therefore also included patients 6 weeks after

**FIGURE 2** Forced vital capacity over time measured with home spirometry (n = 101). The black line indicates the modelled trajectory based on the mixed model results, including the 95% CI in grey.
FIGURE 3 Patient-reported outcome measures over time. The black line indicates the modelled trajectory based on the mixed model results, including the 95% CI in grey. (A) Visual analogue scale (VAS) on cough ($n = 106$). (B) VAS on dyspnoea ($n = 106$). (C) Global rating of change ($n = 109$). (D) Fatigue assessment scale ($n = 111$).

FIGURE 4 Patient experiences with the home monitoring app and home spirometry, scored on visual analogue scales from 0 to 10. High scores indicate better experiences with the home monitoring app, except for ‘burdensome’ where scores are reversed.
discharge, during regular outpatient clinic visits. Second, due to different follow-up schedules at the participating hospitals, we did not have access to serial in-hospital lung function measurements.

In conclusion, this study has provided detailed insights in recovery trajectory of patients hospitalized due to COVID-19. Six months after hospital admission, patients’ lung function and quality of life were still improving, although fatigue persisted. Home monitoring programmes enable long-term detailed monitoring of patients and can facilitate personalized follow-up strategies in the future for patients with COVID-19 at low burden for patients and for the healthcare system.

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CONFLICT OF INTEREST

None declared.

AUTHOR CONTRIBUTION

Gizal Nakshbandi: Data curation (lead); formal analysis (lead); investigation (lead); methodology (lead); project administration (lead); resources (lead); software (lead); visualization (lead); writing – original draft (lead).

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

HUMAN ETHICS APPROVAL DECLARATION

The study was performed in accordance with the Declaration of Helsinki, and approved by the Medical Ethics Committee of the Erasmus Medical Center (MEC-2020-0318) and participating sites. All participants provided written informed consent.

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REFERENCES

1. World Health Organization. WHO Health Emergency Dashboard. Available from: https://covid19.who.int/. [Cited 28 February 2022].

2. Reese H, Iuliano AD, Patel NN, Garg S, Kim L, Silke BJ, et al. Estimated incidence of coronavirus disease 2019 (COVID-19) illness and hospitalization – United States, February-September 2020. Clin Infect Dis. 2021;72(12):e1010–e7.

3. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet. 2020;395(10233):497–506.

4. Halpin SJ, McVor C, Whyatt G, Adams A, Harvey O, McLean L, et al. Postdischarge symptoms and rehabilitation needs in survivors of COVID-19 infection: a cross-sectional evaluation. J Med Virol. 2021;93(2):1013–22.

5. Moreno-Pérez O, Merino E, Leon-Ramirez JM, Andres M, Ramos JM, Arenas-fiménez J, et al. Post-acute COVID-19 syndrome. Incidence and risk factors: a Mediterranean cohort study. J Infect. 2021;82(3):378–83.

6. Huang L, Yao Q, Gu X, Wang Q, Ren L, Wang Y, et al. 1-year outcomes in hospital survivors with COVID-19: a longitudinal cohort study. Lancet. 2021;398(10302):747–58.

7. Huang C, Huang L, Wang Y, Li X, Ren L, Gu X, et al. 6-month outcomes of COVID-19 in patients discharged from hospital: a cohort study. Lancet. 2021;397(10270):220–32.

8. Writing Committee for the COMBAC Study Group, Morin I, Savale L, Pham T, Colle R, Figueiredo S, et al. Four-month clinical status of a cohort of patients after hospitalization for COVID-19. JAMA. 2021;325(15):1525–34.

9. Raghu G, Wilson KC. COVID-19 interstitial pneumonia: monitoring the clinical course in survivors. Lancet Respir Med. 2020;8(9):839–42.

10. Moor CC, Wapenaar M, Miedema JR, Geelhoed JJM, Chandoesing PP, Wijnenbeek MS. A home monitoring program including real-time wireless home spirometry in idiopathic pulmonary fibrosis: a pilot study on experiences and barriers. Respir Res. 2018;19(1):105.

11. Moor CC, van Manen MJG, Tak NG, van Noort E, Wijnenbeek MS. Development and feasibility of an eHealth tool for idiopathic pulmonary fibrosis. Eur Respir J. 2019;53(1):1702508.

12. Moor CC, Gür-Demirel Y, Wijnenbeek MS. Feasibility of a comprehensive home monitoring program for sarcoidosis. J Pers Med. 2019;9(2):23.

13. Moor CC, Mostard RLM, Grutters JC, Bresser P, Aerts J, Chavannes NH, et al. Home monitoring in patients with idiopathic pulmonary fibrosis. A randomized controlled trial. Am J Respir Crit Care Med. 2020;202(3):393–401.

14. Nakshbandi G, Moor CC, Wijnenbeek MS. Home monitoring for patients with ILD and the COVID-19 pandemic. Lancet Respir Med. 2020;8(12):1172–4.

15. Herdman M, Gudex C, Lloyd A, Janssen M, Kind P, Parkin D, et al. Development and preliminary testing of the new five-level version of EQ-5D (EQ-5D-5L). Qual Life Res. 2011;20(10):1727–36.

16. de Kleijn WP, De Vries J, Wijnen PA, Drent M. Minimal (clinically) important differences for the Fatigue Assessment Scale in sarcoidosis. Respir Med. 2011;105(9):1388–95.
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17. Kamper SJ, Maher CG, Mackay G. Global rating of change scales: a review of strengths and weaknesses and considerations for design. J Man Manip Ther. 2009;17(3):163–70.
18. van Noort EMJ, Claessen D, Moor CC, Berg C, Kasteleyen MJ, In’t Veen J, et al. Online tool for the assessment of the burden of COVID-19 in patients: development study. JMIR Form Res. 2021;5(3):e22603.
19. Goossens LMA, Rutten-van Mölken M, Boland MRS, Donkers B, Jonker MF, Slok AHM, et al. ABC Index: quantifying experienced burden of COPD in a discrete choice experiment and predicting costs. BMJ Open. 2017;7(12):e017831.
20. Quanjer PH, Stanojevic S, Cole TJ, Baur X, Hall GL, Culver BH, et al. Multi-ethnic reference values for spirometry for the 3-95-yr age range: the global lung function 2012 equations. Eur Respir J. 2012;40(6):1324–43.
21. Stanojevic S, Graham BL, Cooper BG, Thompson BR, Carter KW, Francis RW, et al. Official ERS technical standards: Global Lung Function Initiative reference values for the carbon monoxide transfer factor for Caucasians. Eur Respir J. 2017;50(3):1700010.
22. Mullab Y. Specification and testing of some modified count data models. J Econom. 1986;33(3):341–65.
23. Min Y, Agresti A. Random effect models for repeated measures of zero-inflated count data. Stat Model. 2005;5:1–19.
24. Wu X, Liu X, Zhou Y, Yu H, Li R, Zhan Q, et al. 3-month, 6-month, and 9-month, and 12-month respiratory outcomes in patients following COVID-19-related hospitalisation: a prospective study. Lancet Respir Med. 2021;9(7):747–54.
25. Yan X, Huang H, Wang C, Jin Z, Zhang Z, He J, et al. Follow-up study of pulmonary function among COVID-19 survivors 1 year after recovery. J Infect. 2021;83(3):381–90.
26. Hui DS, Joynt GM, Wong KT, Gomersall CD, Li TS, Antonio G, et al. Impact of severe acute respiratory syndrome (SARS) on pulmonary function, functional capacity and quality of life in a cohort of survivors. Thorax. 2005;60(5):401–8.
27. Das KM, Lee EY, Singh R, Enani MA, Al Dossari K, Van Gorkom K, et al. Follow-up chest radiographic findings in patients with MERS-CoV after recovery. Indian J Radiol Imaging. 2017;27(3):342–9.
28. Chaudhary S, Natt B, Bime C, Knox KS, Glassberg MK. Antifibrotics in COVID-19 lung disease: let us stay focused. Front Med. 2020;7:539.
29. George PM, Wells AU, Jenkins RG. Pulmonary fibrosis and COVID-19: the potential role for antifibrotic therapy. Lancet Respir Med. 2020;8(8):807–15.
30. Proal AD, VanElzakker MB. Long COVID or post-acute sequelae of COVID-19 (PASC): an overview of biological factors that may contribute to persistent symptoms. Front Microbiol. 2021;12:698169.
31. Hellemons ME, Huijts S, Bek I, Berentschot J, Nakshbandi G, Schurink CAM, et al. Persistent health problems beyond pulmonary recovery up to 6 months after hospitalization for SARS-CoV-2; a longitudinal study of respiratory, physical and psychological outcomes. Ann Am Thorac Soc. 2022;19(4):551–61.
32. Versteeg MM, Vermeulen KM, Evers SMAA, de Wit GA, Prenger R, Stolk EA. Dutch tariff for the five-level version of EQ-5D. Value Health. 2016 Jun;19(4):343–52.
33. Dirikgil E, Roos R, Groeneveld GH, Heringhaus C, Silven AV, Petrus AHJ, et al. Home monitoring reduced short stay admissions in suspected COVID-19 patients: COVID-box project. Eur Respir J. 2021;58(2):2100636.
34. Gootenberg DB, Kurtzman N, O’Mara T, Ge JY, Chiu D, Shapiro NI, et al. Developing a pulse oximetry home monitoring protocol for patients suspected with COVID-19 after emergency department discharge. BMJ Health Care Inform. 2021;28(1):e100330.
35. Grooters LA, Majoor KI, Pol-Mattern ESK, Hardeman JA, van Swol CFP, Vorselaars ADM. Home-monitoring reduces hospital stay for COVID-19 patients. Eur Respir J. 2021;58(5):2101871.
36. Moor C, Mostard RLM, Grutters JC, Bresser P, Aerts JG, Chavannes NH, et al. A randomized controlled trial of a home monitoring program in newly treated patients with idiopathic pulmonary fibrosis. Am J Respir Crit Care Med. 2020;201(1):393–401.
37. Moor CC, van den Berg CAL, Visser LS, Aerts JGJV, Cottin V, Wijsenbeek MS. Diurnal variation in forced vital capacity in patients with fibrotic interstitial lung disease using home spirometry. ERJ Open Res. 2020;6(1):00054-2020.
38. Wootton SL, King M, Alison JA, Mahadev S, Chan ASL. COVID-19 rehabilitation delivered via a telehealth pulmonary rehabilitation model: a case series. Respirology Case Rep. 2020;8(8):e00669.

SUPPORTING INFORMATION
Additional supporting information may be found in the online version of the article at the publisher’s website.

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