The COVID-19 pandemic and vulnerable older persons: impact of a public health emergency on nursing homes and geriatric rehabilitation

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Part 2

Recovery of COVID-19 patients admitted to geriatric rehabilitation

7

Post-COVID-19 Patients in Geriatric Rehabilitation substantially Recover in Daily Functioning and Quality of Life: A European longitudinal cohort study

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ABSTRACT

Background: After an acute infection older persons may benefit from geriatric rehabilitation (GR).

Objectives: This study describes the recovery trajectories of post-COVID-19 patients undergoing GR, and explores whether frailty is associated with recovery.

Design: Multicentre prospective cohort study.

Setting: 59 GR facilities in 10 European countries.

Participants: Post-COVID-19 patients admitted to GR between October 2020 and October 2021.

Methods: Patients' characteristics, daily functioning (Barthel index; BI), quality of life (QoL; EQ-5D-5L), and frailty (Clinical Frailty Scale; CFS) were collected at admission, discharge, 6 weeks and 6 months after discharge. We used linear mixed models to examine the trajectories of daily functioning and QoL.

Results: 723 participants were included with a mean age of 75 (SD: 9.91) years. Most participants were pre-frail to frail (median [interquartile range] CFS 6.0 [5.0–7.0]) at admission. After admission the BI first steeply increased from 11.31 with 2.51 (SE 0.15, $P < 0.001$) points per month, and stabilised around 17.0 (quadratic slope: -0.26, SE 0.02, $P < 0.001$). Similarly, EQ-5D-5L first steeply increased from 0.569 with 0.126 points per month (SE 0.008, $P < 0.001$), and stabilised around 0.8 (quadratic slope -0.014, SE 0.001, $P < 0.001$). Functional recovery rates were independent of frailty level at admission. QoL was lower at admission for frailer participants, but increased faster, stabilizing at almost equal QoL values for frail, pre-frail and fit patients.

Conclusions: Post-COVID-19 patients admitted to GR showed substantial recovery in daily functioning and QoL. Frailty at GR admission was not associated with recovery and should not be a reason to exclude patients from GR.

Key words: geriatric rehabilitation, COVID-19, recovery, older people

KEY POINTS:

- Post-COVID-19 patients from Geriatric Rehabilitation (GR) centres across 10 European countries showed substantial recovery.
- Recovery in daily functioning and quality of life was independent of frailty level at admission to GR following COVID-19.
- Frailty should not be a reason to exclude patients from GR, as even frail people may considerably benefit from post-acute care.

INTRODUCTION

The COVID-19 pandemic was associated with millions of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-COV-2) infections and deaths worldwide, but the highest infection rates and most severe infections were among older people (1-5). Older people with SARS-CoV-2 infection were more often admitted to hospital and to Intensive Care Unit (ICU), with periods of immobility as a consequence (6).

Under normal circumstances older people experiencing acute deterioration in their health and functional status would be offered Geriatric Rehabilitation (GR) (7-9). GR is aimed at people with complex health problems, including pre-existing multimorbidity, cognitive impairment, frailty, or other geriatric syndromes (10). GR can be provided in diverse care settings (11). During the COVID-19 pandemic, the availability of GR care was diminished due to illness among staff, secondment to acute care wards, repurposing of GR facilities as isolation beds for SARS-CoV-2 positive patients, and reduced capacity due to pandemic-related spacing requirements (12). This reduction in rehabilitation supply at a time when demand increased due to many older people experiencing acute health deteriorations due to COVID-19 has been called the 'COVID-19 rehabilitation paradox' (12, 13).

Future pandemic planning should include more effective provision of rehabilitation. Therefore, we need to know whether GR is successful in this context, what type of rehabilitation care to deliver and what population sub-groups, are likely to benefit (10, 14). Evidence on recovery trajectories for people in GR post-COVID still limited, but suggests that people participating in GR post-COVID experienced at least partial recovery (15-18). Outside the context of COVID-19, frailty and functional decline are both frequently used criteria in triage of acutely hospitalised patients for referral to GR (19). Moreover, frailty in older people has been associated with lower functional status (20, 21) and quality of life (QoL) (22). Against this background, in this study we aim to: describe the recovery trajectories in daily functioning and QoL of geriatric patients after COVID-19 in a multicentre, multinational European cohort during GR and up to 6 months after discharge; and explore whether the patient's frailty level at GR admission is associated with recovery in daily functioning and QoL.

METHODS

Design

The European Cooperation in Geriatric Rehabilitation study after COVID-19 (EU-COGER) was an international multicentre prospective observational cohort study. This study was designed by the Special Interest Group for Geriatric Rehabilitation of the European Geriatric Medical Society (EuGMS) and registered in ClinicalTrials.gov (identifier: NCT05749731).

Participants and setting

The terminology and definitions used for GR differ between countries. In this study we defined GR facilities, in line with the consensus definition for GR developed by the EuGMS (11), as facilities that provide multidisciplinary rehabilitation care to frail and/or multimorbid patients. Participants were recruited from the Czech Republic, Germany, Ireland, Israel, Italy, Malta, Russia, Spain, the Netherlands, and the United Kingdom between October 2020 to October 2021 (7). Both inpatient GR facilities and GR facilities that provided care at home were included in the EU-COGER consortium (**Appendix I).**

To be included, patients had to be receiving rehabilitation in one of the participating facilities as part of recovery from a SARS-CoV-2 infection, confirmed with either: Polymerase Chain Reaction (PCR) for viral RNA; or serology for antibodies against SARS-CoV-2. Potential participants with severe cognitive impairment which led to insufficient decisional capacities to participate in the study were excluded (7).

Ethics

The Leiden University Medical Center COVID-19 science ethical committee deemed this study exempt from the Medical Research Involving Human Subjects Act (Wet medisch-wetenschappelijk Onderzoek met mensen, WMO) since the study only used routinely collected data, and approved the study based on an opt-out procedure for the Netherlands (protocol number CoCo 2020-040). In all other countries, the local ethical regulations were followed and approval from local ethics committee was granted as per local regulations.

Data collection

Routine medical care data from health records were collected at admission to GR, and at discharge, including data from two weeks pre-morbid (pre-COVID) status from admission documentation (7). In addition, participating facilities were asked to collect data through telephone follow-ups at 6 weeks and 6 months after discharge. Local study coordinators entered participant data into an online CASTOR (23) database using standard

operating procedures (24). A complete overview of the procedures and all measures collected is described in the published protocol paper (7).

Outcome measures chosen were based on instruments readily available in multiple languages and cross-culturally validated. The primary outcome measure was daily functioning, assessed with the Barthel Index (BI) for activities of daily living (ADL) at all time points (25). When certain countries or facilities used comparable measures, i.e. the Utrecht Scale for the Evaluation of Rehabilitation (USER) or the Functional Independence Measure (FIM), these were converted to the BI using standardised approaches (26, 27). The BI is a 10-item instrument that produces a total score that ranges from 0 to 20, with higher scores indicating higher independence in ADL.

The secondary outcome measure was health related QoL assessed with the EQ-5D-5L, available in over 150 languages (28). EQ-5D-5L was assessed at all timepoints except pre-morbid, and is a 5-item instrument that produces a 5-digit status for mobility, self-care, daily activities, pain, and anxiety/depression. Using an available country tariff, this status can be calculated into a societal value of maximum 1 for optimal QoL (29-34). Malta, Czech Republic, and Russia had no country tariff available and the geographically closest available country tariff (Spain, Poland, and Poland respectively) was used (32, 35). There was no QoL data available for Israeli participants, as data necessary for EQ-5D-5L were not collected as part of routine practice.

Frailty, the independent variable of interest, was measured using the Clinical Frailty Scale (CFS). This ranks frailty on a scale from level 1 to 9, with level 1 'very fit', to 9 'terminally ill' (36). Premorbid frailty level and frailty level at GR admission were collected. Other variables collected include demographic characteristics, clinical characteristics, and received treatment components (**Table 1**).

Statistical analysis

Descriptive statistics were used to give an overview of participants' demographic and clinical characteristics, and treatment components. Continuous variables were reported with mean and SD or median and interquartile range (IQR), depending on whether data were normally distributed. Categorical variables were presented as number (n) and percentage (%).

The recovery trajectories in daily functioning and QoL during and after GR were examined by linear mixed models, with time in months since GR admission. For each outcome measure, three models were built. Unconditional models were used to illustrate the change in daily functioning and QoL of the study population over time, independent

of covariates. To identify the best fitting unconditional models, the following steps were taken: first, we tested whether the fixed slopes were linear or quadratic; second, we tested whether adding random intercept parameters for variance between persons and between countries improved the model fit; third, we tested whether adding random linear and quadratic slope parameters for variance between persons and variance between countries improved the model fit. In every step, we fitted models using the default optimizer in the lmer R function 'nloptwrap', and optimizer 'Neldermead' that has been specially developed to find solutions of boundary fits (37). The model with the highest loglikelihood value (for nested models) or the lowest Akaike Information Criterion value (for non-nested models) was chosen (38). Models were built with unstructured variance-covariance matrices. For daily functioning a premorbid value was available, but not for QoL. Therefore, we were able to add a linear spline from premorbid to GR admission in the models for daily functioning.

Subsequently, the effect of frailty at GR admission on recovery in daily functioning and QoL was examined in univariable models and in multivariable models adjusted for age, sex, premorbid daily functioning, comorbidities (Functional Comorbidity Index) (39), hospital length of stay (days), and ICU stay (yes/no). All independent variables were mean-centred, to present the recovery trajectory in daily functioning and QoL for a sample mean participant. In the same way, the effect of premorbid frailty on trajectories of daily functioning and QoL was examined in a sensitivity analysis. Additionally, we tested whether participants with missing values in the independent variables, who had to be excluded from complete case analysis, had similar recovery trajectories as the included participants.

Outcomes were presented as parameter estimates (SE) for the fixed and random effects of the mixed models. All models were built using R version 4.2.2 and R function lmer for linear mixed models from R package lme4. The effect of frailty is illustrated in graphs for three stages of frailty defined as fit (CFS 1-3), pre-frail (CFS 4-5), and frail (CFS 6-9) (40, 41).

RESULTS

Participants

Participants were recruited from 59 rehabilitation facilities **i**n 10 European countries. Records for 793 participants were created in the database. After the exclusion of participants from rehabilitation centres that withdrew from study participation (n = 7), dupli-

cates (n = 2), empty records (n = 10), and participants who did not meet the inclusion criteria (n = 51), the cohort consisted of 723 participants (**Figure 1**).

Participants' mean age was 75 years (SD 9.9) and most of them had been admitted to the hospital prior to GR (n = 653; 90.3%). While premorbid most participants were fit or pre-frail (n = 490, CFS 3.0, IQR 2.0 – 4.0), at GR admission most participants were frail or pre-frail (n = 493, median CFS 6.0, IQR 5.0 – 7.0). More than half of the participants received physiotherapy (88.9%), occupational therapy (69.7%), and a protein or calorie-enriched diet (65.3%) during GR. The median length of stay in GR was 26.0 days (IQR 15.0 – 41.0) (**Table 1**). The available numbers of daily functioning and QoL scores for each timepoint is presented in **Appendix II**.

Data of respectively 388 and 330 participants was complete for all covariates and had outcome data for at least one of the timepoints and could be included in the linear mixed models (**Figure 1**). There were no clinically relevant differences between the recovery trajectories for participants included and excluded from the models for daily functioning.

Table 1. Demographic characteristics, clinical characteristics, and received treatment components and outcomes of post-COVID-19 patients in geriatric rehabilitation

Characteristic	*n* (%) available	Value
Age, mean (SD)	719 (99.4)	75.49 (9.91)
Sex, male, *n* (%)	723 (100)	379 (52.4)
Country, *n* (%)	723 (100)	
Czech republic		53 (7.3)
Germany		50 (6.9)
Ireland		50 (6.9)
Israel		32 (4.4)
Italy		30 (4.1)
Malta		17 (2.4)
Russia		50 (6.9)
Spain		96 (13.3)
the Netherlands		293 (40.6)
United Kingdom		52 (7.2)
Barthel index at GR admission, mean (SD)	714 (98.8)	10.94 (5.40)
EQ-5D-5L at GR admission, mean (SD)	471 (65.1)	0.52 (0.32)
Clinical Frailty Scale (CFS) premorbid, median (IQR)	490 (67.8)	3.0 (2.0 – 4.0)
fit (CFS 1-3)		283 (39.1)
pre-frail (CFS 4 – 5)		149 (20.6)
frail (CFS 6 – 9)		58 (8.0)

Table 1. Demographic characteristics, clinical characteristics, and received treatment components and outcomes of post-COVID-19 patients in geriatric rehabilitation (*continued*)

Characteristic	*n* (%) available	Value
Clinical Frailty Scale (CFS) at GR admission, median (IQR)	493 (68.2)	6.0 (5.0 – 7.0)
fit (CFS 1-3)		51 (7.1)
pre-frail (CFS 4 – 6)		129 (17.8)
frail (CFS 7 – 9)		313 (43.3)
Functional Comorbidity Index, median (IQR)	634 (87.7)	3.0 (2.0 – 4.0)
Hospital stay preadmission, n (%)	720 (99.6)	653 (90.3)
Hospital length of stay, days, median (IQR)	645 (89.2)	23.0 (13.0 – 46.5)
ICU stay preadmission, yes, n (%)	711 (98.3)	240 (33.2)
ICU length of stay, days, median (IQR)	232 (32.1)	23.0 (11.0 – 43.0)
Living situation premorbid, *n* (%)	720 (99.6)	
own home		675 (93.4)
nursing home/assisted living		42 (5.8)
other		3 (0.4)
Treatment components of GR, *n* (%)	670 (92.7)	
oxygen therapy		289 (40.0)
physiotherapy (total)		595 (82.3)
physiotherapy for sarcopenia		496 (74.0)
physiotherapy for lung function		408 (60.9)
occupational therapy (total)		467 (64.6)
occupational therapy for iADL		421 (62.8)
occupational therapy for house adaptations		273 (40.7)
speech/language therapy (total)		126 (17.4)
speech/language therapy for dysphagia		93 (13.9)
speech/language therapy for voice/speech		61 (9.1)
protein or calorie enriched diet		437 (60.4)
psychosocial support		170 (23.5)
cognitive training		82 (11.3)
Length of stay in GR, days; median (IQR)	701 (97.0)	26.0 (15.0 – 41.0)
Discharge destination, *n* (%)	703 (97.2)	
own home		544 (75.2)
nursing home/assisted living		103 (14.3)
hospital		30 (4.1)
other		15 (2.1)
deceased during GR		11 (1.5)
Post-Traumatic Stress Disorder (PTSS) at 6 weeks and/or 6 months after GR discharge, *n* (%)	541 (74.8)	59 (8.16)

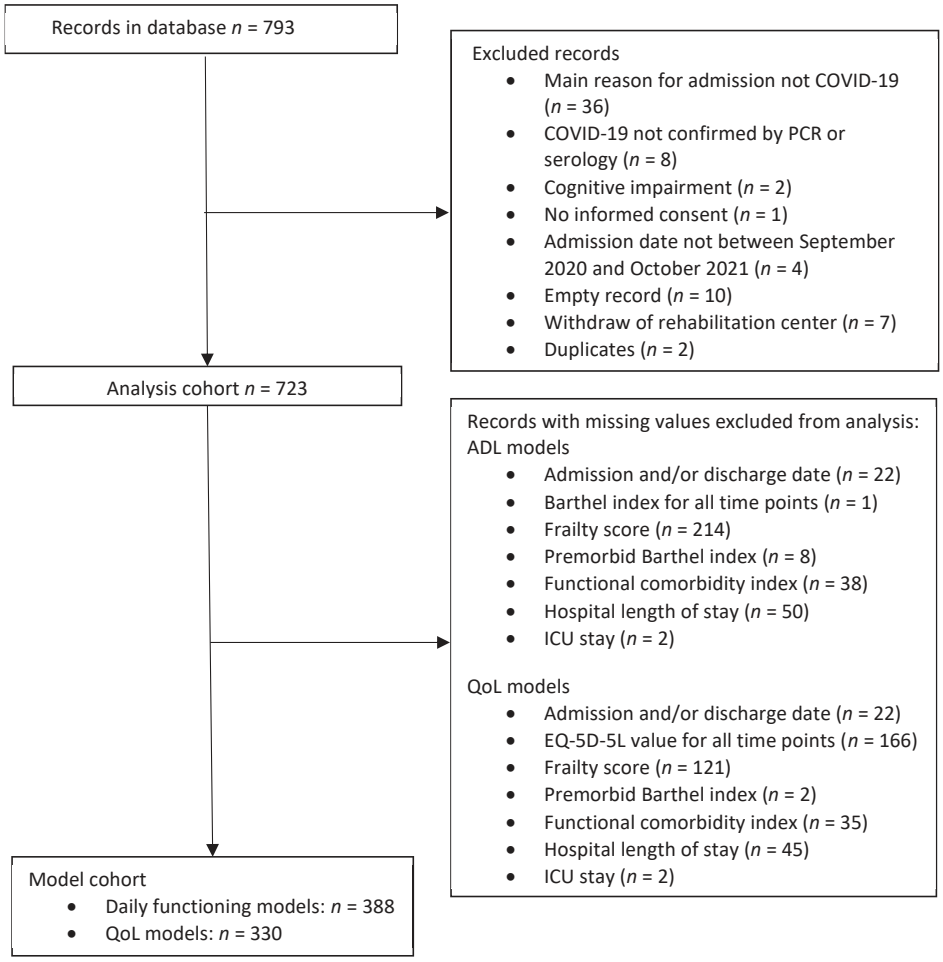

Figure 1. Flowchart of study participants

Daily functioning over time

The best fitting unadjusted model for the recovery trajectory of daily functioning showed that BI decreased during acute COVID infection from 17.41 before GR admission to 11.31 BI (SE 0.81, $P < 0.001$; **Table 2**) at GR admission. After GR admission, the largest increase in BI was seen within the first three months: BI first steeply increased with 2.51 (SE 0.18, $P < 0.001$) points BI per month, and stabilised (quadratic slope -0.26 BI per month squared, SE 0.02, $P < 0.001$) around 17.0 (**Figure 2A**). This best fitting model contained random intercepts and slopes for participants and countries.

The multivariate model showed that BI for daily functioning at GR admission was significantly lower for participants who were frailer at GR admission, estimated as 0.90 (SE 0.11, $P < 0.001$) points lower BI for each point that CFS is higher (**Table 2**). Frailty at GR admission

had little effect on the rate of recovery in daily functioning (linear slope -0.17 points BI per point CFS per month, SE 0.09, $P = 0.075$; quadratic slope 0.04 points BI per point CFS per month squared, SE 0.01, $P = 0.007$). **Figure 2B** shows that the recovery trajectories of daily functioning for participants of different frailty stages were almost parallel to each other.

Sensitivity analysis showed that premorbid frailty had a stronger association with the rate of recovery in daily functioning compared to frailty at GR admission. Participants who were frail premorbid (CFS 6-9, $n = 49$) recovered more slowly, leading to only partial recovery in daily functioning (**Appendix III: Table 5, Figure 3A**).

Table 2. Linear mixed models for change in daily functioning over time (unconditional model) and effect of frailty (univariable and multivariable models) ($n = 388$)

	Unadjusted model		**Univariable model**		**Multivariable model***	
	Estimate (SE)	***P*-value**	**Estimate (SE)**	***P*-value**	**Estimate (SE)**	***P*-value**
Fixed effects						
At admission (intercept)						
Daily functioning (Barthel Index; range 0-20)	11.31 (0.81)	<0.001	11.51 (0.46)	<0.001	11.64 (0.31)	<0.001
Frailty (Clinical Frailty Scale; range 1-9)	N/A	N/A	-1.50 (0.13)	<0.001	-0.90 (0.11)	<0.001
Change before admission (slope)						
Change per week	- 3.05 (0.11)	<0.001	- 3.08 (0.11)	<0.001	- 3.10 (1.06)	<0.001
Change after admission (slope)						
Per month: linear component	2.51 (0.15)	<0.001	2.58 (0.15)	<0.001	2.73 (0.14)	<0.001
Per frailty score: linear component	N/A	N/A	-0.13 (0.09)	0.170	-0.17 (0.09)	0.075
Per month: quadratic component	-0.26 (0.02)	<0.001	-0.28 (0.02)	<0.001	-0.30 (0.02)	<0.001
Per frailty score: quadratic component	N/A	N/A	0.03 (0.01)	0.019	0.04 (0.01)	0.007
	Variance (SD)		**Variance (SD)**		**Variance (SD)**	
Random effects						
At admission (intercept)						
Between persons variance	8.13 (2.85)		5.40 (2.32)		1.50 (1.23)	
Between countries variance	6.00 (2.45)		1.72 (1.31)		0.70 (0.84)	
After admission (slope of change)						
Between persons variance	0.03 (0.19)		0.04 (0.20)		0.05 (0.22)	
Between countries variance	0.07 (0.26)		0.05 (0.22)		0.01 (0.10)	
Residual	10.64 (3.26)		10.52 (3.24)		9.98 (3.16)	

N/A, not available. *Adjusted for age, sex, premorbid BI, Functional Comorbidity Index, hospital length of stay, and ICU stay.

Quality of life over time

The best fitting unadjusted model for the recovery trajectory of QoL showed that the largest increase was seen within the first two months: The EQ-5D-5L value also first steeply increased from 0.569 (SE 0.047, $P < 0.001$; **Table 3**) at GR admission with 0.126 (SE 0.008, $P < 0.001$) per month, after which it stabilised (quadratic slope -0.014 points EQ-5D-5L per month squared, SE 0.001, $P < 0.001$) around 0.8 (**Figure 2C**). This best fitting model contained random intercepts for participants and countries and a random slope for participants.

Table 3. Linear mixed models for change in quality of life over time (unconditional model) and effect of frailty (univariable and multivariable models ($n = 330$)

	Unadjusted model		**Univariable model**		**Multivariable model***	
	Estimate (SE)	***P*-value**	**Estimate (SE)**	**P-value**	**Estimate (SE)**	***P*-value**
Fixed effects						
At admission (intercept)						
Quality of life (EQ-5D-5L; range 0-1)	0.569 (0.047)	<0.001	0.566 (0.037)	<0.001	0.587 (0.031)	<0.001
Frailty (Clinical Frailty Score; range 1-9)	N/A	N/A	-0.098 (0.01)	<0.001	-0.075 (0.010)	<0.001
Change after admission (slope)						
Per month: linear component	0.126 (0.008)	<0.001	0.125 (0.008)	<0.001	0.124 (0.008)	<0.001
Per frailty score: linear component	N/A	N/A	0.027 (0.006)	<0.001	0.023 (0.007)	<0.001
Per month: quadratic component	-0.014 (0.001)	<0.001	-0.014 (0.001)	<0.001	-0.014 (0.001)	<0.001
Per frailty score: quadratic component	N/A	N/A	-0.003 (0.001)	0.006	-0.002 (0.001)	0.033
	Variance (SD)		**Variance (SD)**		**Variance (SD)**	
Random effects						
At admission (intercept)						
Between persons variance	0.035 (0.187)		0.026 (0.160)		0.022 (0.148)	
Between countries variance	0.018 (0.132)		0.011 (0.103)		0.007 (0.082)	
After admission (slope of change)						
Between persons variance	0.001 (0.032)		0.001 (0.029)		0.001 (0.025)	
Residual	0.030 (0.172)		0.029 (0.171)		0.029 (0.170)	

N/A, not available. *Adjusted for: age, sex, premorbid BI, Functional Comorbidity Index, hospital length of stay, and ICU stay.

The multivariate model found that EQ-5D-5L values for QoL at GR admission were much lower for participants who were frailer at GR admission, estimated as 0.07 (SE 0.01, $P <$

0.001) points lower EQ-5D-5L for each point that CFS is higher (**Table 3**). Frailty at GR admission was also associated with the rate of recovery in daily functioning. EQ-5D-5L values increased steeper for frailer participants (linear slope 0.02 higher EQ-5D-5L value per point CFS per month, SE 0.01, $P < 0.001$; quadratic slope <-0.00 lower EQ-5D-5L value per point CFS per month squared, SE 0.00, $P = 0.033$). **Figure 2D** shows that within some months this led to almost equal EQ-5D-5L values for frail, pre-frail and fit participants.

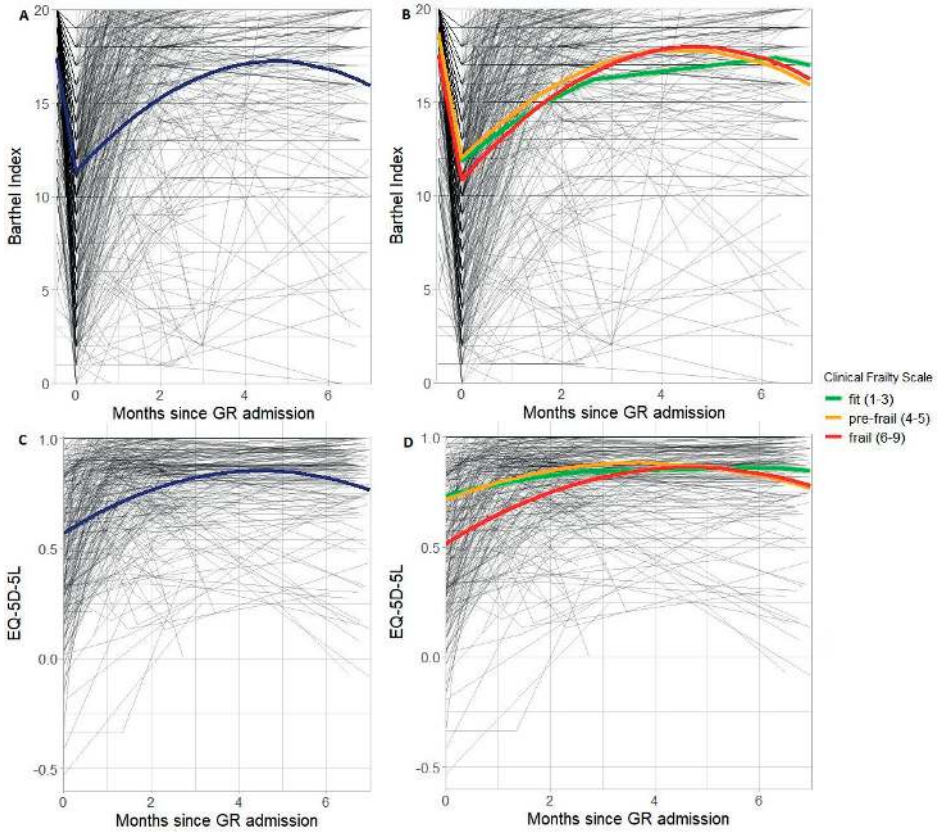

Figure 2. A, Unconditional trajectory of daily functioning (n = 388). **B,** Trajectory of daily functioning for fit (n = 34), pre-frail (n = 102), and frail (n = 252) participants at GR admission (n = 388). **C**, Unconditional trajectory of quality of life (n = 330). **D**, Trajectory of quality of life for fit (n = 33), pre-frail (n = 95), and frail (n = 202) participants at GR admission (n = 330).

Sensitivity analysis showed that the association between premorbid frailty and the rate of recovery in QoL was similar to the association for frailty at GR admission: the rate of recovery in QoL was higher for frailer participants (**Appendix III: Table 6, Figure 3B**).

DISCUSSION

This study showed that European patients admitted to GR following COVID-19 recovered in daily functioning almost up to their premorbid status. Their QoL also substantially increased. The largest increases in QoL and daily functioning were observed within the first 2 or 3 months after GR admission. A large proportion of geriatric post-COVID-19 patients were frail at GR admission. These frail patients recovered in daily functioning approximately as fast as more fit patients. Although QoL was lower at admission for patients who were frail (either at GR admission or prior to the infection), their recovery went faster compared to fitter patients, leading to equal levels of QoL after a couple of months.

This study was performed during a period when healthcare systems were severely strained and this likely reduced the quality of rehabilitation care. Patients were sometimes discharged early from the hospital (42). Consequently, possibly patients were frailer than usual at GR admission. Therefore, the observed recovery may be an underestimation of the potential recovery of post-COVID-19 patients. Moreover, post-COVID-19 GR patients in our cohort (mean age 75, SD 9.9) tend to be a little younger than pre-pandemic GR patients (mostly patients recovering from stroke, complex conditions, hip fracture, or repeated falls), who have a mean age of 80 (SD 4.3) (43).

Literature about older COVID-19 patients who did not receive rehabilitation care after hospitalization shows that the majority of them did not fully recover. In a French and in a Spanish cohort, one third had a lower functional status at three months after hospitalization than they had at hospital admission (44, 45). Moreover, the majority experienced cognitive decline, depressive symptoms, required readmission, or died (44); or experienced fatigue, frailty, or died (45). Two third of the older post-COVID-19 patients in a Norwegian cohort reported a decline in any of the EQ-5D-5L dimensions from their premorbid situation to 6 months after hospital discharge (46). Frailty, either measured premorbid or at hospital admission, has been shown to be associated with mortality in hospitalised older people with COVID-19 (41, 47, 48).

The present study found that for patients who were admitted to GR, frailty at admission was not distinctive for recovery. Even patients who were frail premorbid partially recovered, though less completely so (**Appendix III**). These findings support inclusivity when selecting patients for GR. Guidelines are ambiguous about the use of frailty as a selection criterion for GR after COVID-19. For example, according to guidance by the EuGMS a geriatric needs assessment, that includes frailty, should be used in the referral decision (10). Guidelines developed by the World Health Organisation do not mention

frailty as a criterion for GR referral (49). Instead, these guidelines describe that rehabilitation programmes should be individualised based on functional limitations (49).

This study has a number of strengths. First, to our knowledge, this is the only study on COVID-19 rehabilitation with a follow-up time of more than 6 months. Second, patients were recruited from 59 rehabilitation facilities in 10 European countries. However, in the Czech Republic, Italy, Israel, and Malta only one care facility participated, which may reduce the generalizability of our results in these countries. Third, this study specifically focused on GR. Little research has been done on COVID-19 in this field.

A limitation of this study is the lack of more detailed outcome measures, such as instrumental ADL (iADL), because only regular care data were collected. Second, few participants were fit at GR admission (n = 51), and few participants were frail prior to the SARS-COV-2 infection (n = 58). Therefore, our results are not very precise for these patient groups. However, this is unlikely to pose large threat to the generalisability of our findings to the GR population, as GR patients are often selected based on their potential to benefit from GR, leading to relatively small numbers of premorbid frail or at admission very fit patients. Third, a large number of participants had to be excluded from the linear mixed models due to missing values. However, it is unlikely that this biased our results. Mixed models handle missing outcome data well under the assumption it is missing at random, and the recovery trajectories of the excluded and included participants were similar. Fourth, due to the wide practice variation, it is unclear whether our results apply to all GR care settings and what optimal GR care constitutes.

In conclusion, this study found that patients admitted to GR following COVID-19 substantially recover in terms of daily functioning and QoL. Even patients who were frail at GR admission substantially recovered, which suggests that post-COVID-19 patients of all stages of frailty have the potential to benefit from GR care and that frailty after acute illness should not be used as a criterion to decline patients access to rehabilitation. However, more research is needed to quantify the association between premorbid frailty and rehabilitation potential. To make statements about what optimal GR care for post-COVID-19 patients constitutes, differences between countries in GR care organization, patient selection, and recovery trajectories should be explored. Barring a deterioration in the current global situation regarding COVID-19, opportunities to conduct similar large scale research in this context are unlikely to arise. The work presented here may be extrapolated to other contexts and acute conditions with similar clinical trajectories to bring our understanding forward of where GR may add value.

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Declaration of Conflicts of Interest:

None

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APPENDIX I. EU-COGER CONSORTIUM LIST

Name of health centre	Country	Study coordinator #1	Study coordinator #2	Study coordinator #3	Study coordinator #4
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Agaplesion Bethanien Hospital	Germany	Stefan Grund	Thomas Mross	Lotte Feesche	
Robert-Bosch-Krankenhaus	Germany	Rebekka Leonhardt	Clemens Becker		
Geriatrisches Zentrum Karlsruhe	Germany	Jan Gerhardus	Brigitte R. Metz		
Geriatrische Rehabilitationsklinik Diakonissenkrankenhaus Mannheim	Germany	Diana Franke-Chowdhury			
University of Limerick Hospital Group (ULHG)	Ireland	Rose Galvin	Aoife McCarthy		
Beaumont Hospital	Ireland	Frances Dockery	Kara McLoughlin		
Fliman geriatric rehabilitation center	Israel	Bahaa Francis			
IRCCS Istituti Clinici Maugeri	Italy	Matteo Cesari	Annalisa Valentini		
Karin Grech Hospital	Malta	Mark Vassallo	Maria Bonnici		
Russian Clinical and Research Center of Gerontology	Russia	Olga Nikolaevna Tkacheva	Ksenia Eruslanova		
Moscow Rehabilitation center	Russia	Luba Matchekhina			
Parc Sanitari Pere Virgili	Spain	Laura Monica Perez Bazan			
Hospital Universitari Sant Joan de Reus	Spain	Esther Roquer Fanlo			
Hospital Universitari Parc de Salut Mar	Spain	Anna Renom Guiteras	Lizzeth Angela Canchucaja		
Hospital Central de la Cruz Roja San José y Santa Adela	Spain	Beatriz Pallardo	Sergio Martínez Zujeros		
Hospital San Joan de Deu Mallorca	Spain	Margarita Viñuela	Oriol Miralles Resina		
Hospital Guadarrama	Spain	Gema Isabel Dominguez	Sarah Caro Bragado		
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Name of health centre	Country	Study coordinator #1	Study coordinator #2	Study coordinator #3	Study coordinator #4
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Leiden University Medical Center	the Netherlands	Wilco Achterberg	Monique Caljouw	Miriam Haaksma	Lisa van Tol
Omring	the Netherlands	Saskia Drijver			
Zorgcirkel	the Netherlands	Paula Vonk			
BrabantZorg	the Netherlands	Liesbeth Sikken	Irma Baars		
Ijsselheem	the Netherlands	Nathalie Deden			
Topaz Revitel	the Netherlands	Gerda Nijgh	Sylvia van der Drift		
Tante Louise	the Netherlands	Heike de Wever	Els Calle		
MUMC+|Herstelzorg – Vitala+	the Netherlands	Kaoutar Karramass	Josette Hendriks		
Axion continu	the Netherlands	Lauren Ebbes			
TriviumMeulenbeltZorg Almelo	the Netherlands	Anne Hartman	Hatice Koc		
TriviumMeulenbeltZorg Hengelo	the Netherlands	Laura de Vries			
Patyna	the Netherlands	Hylco Bouwstra			
Careyn	the Netherlands	Laura Langendoen-Wigman			
Sensire	the Netherlands	Berber Oldenbeuving	Sabine Noordam-Hemeltjen		
Azora	the Netherlands	Liesbeth Lanting	Lulu Andela		
Argos Zorggroep	the Netherlands	Mathilde Meerkerk			
Meriant (Alliade)	the Netherlands	Lianne Willemstein	Krisztina Krasznai		
Liemerije	the Netherlands	Janneke Wolting			
Laurens Intermezzo Zuid	the Netherlands	Janette Tazmi			
de Wever	the Netherlands	Eveline Keustermans			

(*continued*)

Name of health centre	Country	Study coordinator #1	Study coordinator #2	Study coordinator #3	Study coordinator #4
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SVRZ 't Gasthuis	the Netherlands	Lenni Boogaard			
De Betuwe, Zorgcentrum Beatrix	the Netherlands	Simone Been			
Archipel Zorggroep	the Netherlands	Danielle Termeer			
Florence	the Netherlands	Patricia te Pas	Eva Lodewijks		
Pieter van Foreest, locatie Bieslandhof	the Netherlands	Jeroen van den Berg			
Reactiveringscentrum Klimop	the Netherlands	Sandra Prent	Marloes Boontje		
Zorgspectrum Nieuwegein	the Netherlands	Joël Harms	Jeffrey Bakker		
Zorggroep Maas en Waal	the Netherlands	Carolien de Croon			
Attent	the Netherlands	Christa van Schieveen			
Vivium Flevoburen (Zorggroep Almere)	the Netherlands	Ewout Smit			
Kennemerhart Schoterhof	the Netherlands	Patricia van Berlo			
Van Neynsel	the Netherlands	Dionne Ruchtie			
Sheffield teaching Hospitals	UK	Jane Manson			
Frimley Health NHS Foundation Trust	UK	Maria Espasandin	Lucy Abbott		
Harrogate District Hospital	UK	Sarah Chadwick	Rebecca Watts		
Imperial College Healthcare NHS Trust	UK	Melani Dani	Jackie McNicholas		
University Hospitals of Derby and Burton	UK	Adam Gordon			
Calderdale & Huddersfield	UK	Vincent Chau			
Derbyshire Community Health Services	UK	Andy Cole			

APPENDIX II. AVAILABILITY OF ADL FUNCTIONING AND QUALITY OF LIFE DATA PER TIMEPOINT

Table 4. Availability of ADL functioning and quality of life data

Outcome measures	***n* (%) available**
ADL functioning (Barthel index)	
premorbid	641 (88.7)
GR admission	714 (98.8)
GR discharge	655 (90.6)
6 weeks after discharge	515 (71.2)
6 months after discharge	509 (70.4)
Quality of life (EQ-5D-5L)	
GR admission	471 (65.1)
GR discharge	413 (57.1)
6 weeks after discharge	423 (58.5)
6 months after discharge	425 (58.8)

APPENDIX III: ADL FUNCTIONING AND QUALITY OF LIFE OVER TIME AND THE EFFECT OF PREMORBID FRAILTY ON THESE TRAJECTORIES

Table 5. Linear mixed models for change in ADL functioning over time (unconditional model) and effect of premorbid frailty (univariable and multivariable models) (n = 389)

	Unadjusted model		**Univariable model**		**Multivariable model***	
	Estimate (SE)	***P*-value**	**Estimate (SE)**	**P-value**	**Estimate (SE)**	***P*-value**
Fixed effects						
At admission (intercept)						
ADL functioning (Barthel Index; range 0-20)	11.35 (0.82)	<0.001	11.73 (0.51)	<0.001	11.65 (0.52)	<0.001
frailty (Clinical Frailty Scale; range 1-9)	N/A	N/A	-1.45 (0.12)	<0.001	-0.29 (0.14)	0.036
Change before admission (slope)						
Change per week	- 3.06 (0.11)	<0.001	- 3.06 (0.11)	<0.001	- 3.10 (1.06)	<0.001
Change after admission (slope)						
Per month: linear component	2.45 (0.15)	<0.001	2.47 (0.15)	<0.001	2.65 (0.14)	<0.001
Per frailty score: linear component	N/A	N/A	-0.06 (0.08)	0.415	-0.38 (0.11)	<0.001
Per month: quadratic component	-0.25 (0.02)	<0.001	-0.26 (0.02)	<0.001	-0.28 (0.02)	<0.001
Per frailty score: quadratic component	N/A	N/A	0.01 (0.01)	0.521	0.04 (0.02)	0.005
	Variance (SD)		**Variance (SD)**		**Variance (SD)**	
Random effects						
At admission (intercept)						
Between persons variance	7.91 (2.81)		5.00 (2.24)		1.65 (1.29)	
Between countries variance	6.31 (2.51)		2.16 (1.47)		2.43 (1.56)	
After admission (slope of change)						
Between persons variance	0.06 (0.25)		0.04 (0.19)		0.04 (0.19)	
Between countries variance	0.07 (0.26)		0.07 (0.26)		0.04 (0.19)	
Residual	10.45 (3.23)		10.51 (3.24)		10.00 (3.16)	

N/A, not available. *Adjusted for: age, sex, premorbid BI, Functional Comorbidity Index, hospital length of stay, and ICU stay.

Table 6. Linear mixed models for change in quality of life over time (unconditional model) and effect of premorbid frailty (univariable and multivariable models (n = 330)

	Unadjusted model		**Univariable model**		**Multivariable model***	
	Estimate (SE)	***P*-value**	**Estimate (SE)**	***P*-value**	**Estimate (SE)**	***P*-value**
Fixed effects						
At admission (intercept)						
Quality of life (EQ-5D-5L; range 0-1)	0.564 (0.047)	<0.001	0.571 (0.040)	<0.001	0.586 (0.037)	<0.001
Frailty (Clinical Frailty Score; range 1-9)	N/A	N/A	-0.041 (0.011)	<0.001	-0.044 (0.01)	0.001
Change after admission (slope)						
Per month: linear component	0.122 (0.008)	<0.001	0.125 (0.008)	<0.001	0.12 (0.014)	<0.001
Per frailty score: linear component	N/A	N/A	0.004 (0.006)	0.535	0.021 (0.008)	0.015
Per month: quadratic component	-0.013 (0.001)	<0.001	-0.014 (0.001)	<0.001	-0.014 (0.001)	<0.001
Per frailty score: quadratic component	N/A	N/A	-0.001 (0.001)	0.288	-0.002 (0.001)	0.077
	Variance (SD)		**Variance (SD)**		**Variance (SD)**	
Random effects						
At admission (intercept)						
Between persons variance	0.036 (0.191)		0.034 (0.185)		0.027 (0.165)	
Between countries variance	0.017 (0.132)		0.012 (0.109)		0.010 (0.101)	
After admission (slope of change)						
Between persons variance	0.001 (0.033)		0.001 (0.032)		0.001 (0.027)	
Residual	0.031 (0.177)		0.031 (0.177)		0.030 (0.173)	

N/A, not available. *Adjusted for: age, sex, premorbid BI, Functional Comorbidity Index, hospital length of stay, and ICU stay.

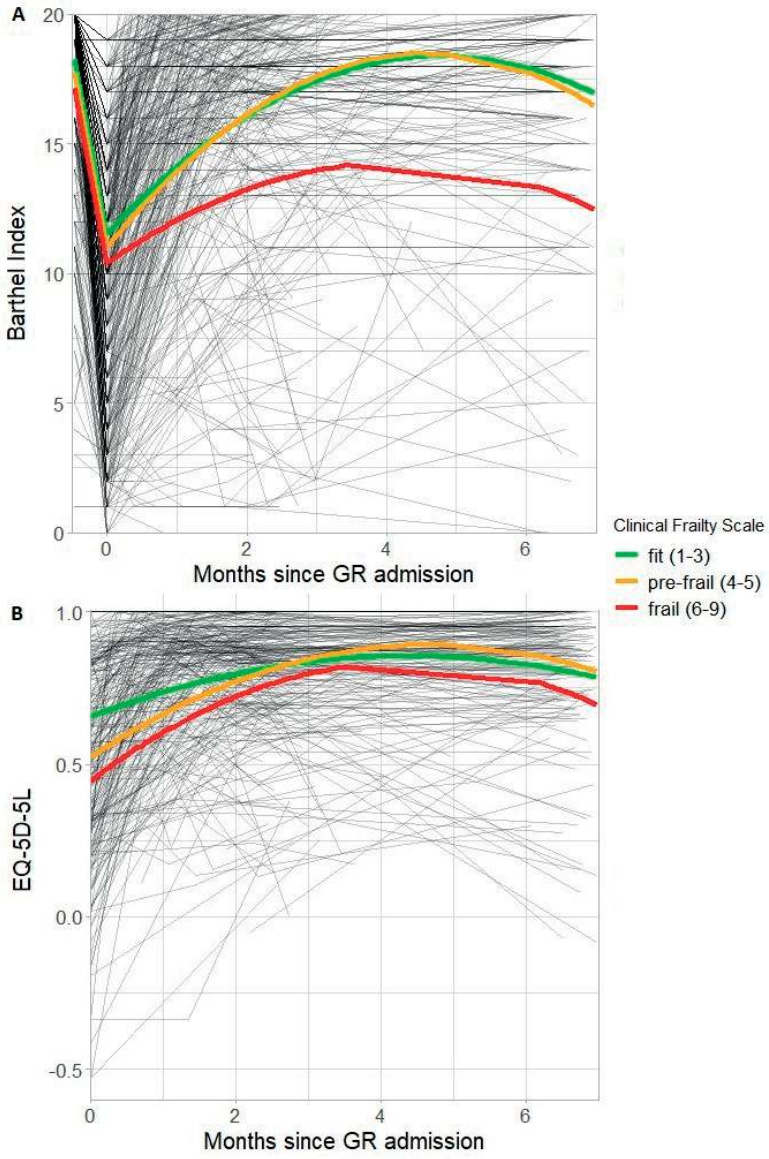

Figure 3. A, Trajectory of ADL functioning for premorbid fit (*n* = 216), pre-frail (*n* = 124), and frail (*n* = 49) participants (*n* = 389). **B**, Trajectory of quality of life for premorbid fit (*n* = 203), pre-frail (*n* = 100), and frail (*n* = 27) participants (*n* = 330).