Post COVID-19 condition, work ability and occupational changes in a population-based cohort

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The Lancet Regional Health - Europe 2023;31: 100671

Published Online 23 June 2023
https://doi.org/10.1016/j.lanepe.2023.100671

Summary

Background Evidence on the impact of post COVID-19 condition (PCC) on work ability is limited but critical due to its high prevalence among working-age individuals. This study aimed to evaluate the association between PCC, work ability, and occupational changes in a population-based cohort.

Methods We used data from working-age adults included in a prospective, longitudinal cohort of a random sample of all individuals infected with SARS-CoV-2 between August 2020 and January 2021 in the Canton of Zurich, Switzerland. We evaluated current work ability, work ability related to physical and mental demands, and estimated future work ability in 2 years (assessed using Work Ability Index), and PCC-related occupational changes one year after infection.

Findings Of 672 individuals included in this study, 120 (17.9%) were categorised as having PCC (defined as presence of self-reported COVID-19 related symptoms) at 12 months. There was very strong evidence that current work ability scores were mean 0.62 (95% CI 0.30–0.95) points lower among those with PCC compared to those without in adjusted regression analyses. Similarly, there was very strong evidence for lower odds of reporting higher work ability with respect to physical (adjusted odds ratio (aOR) 0.30, 95% CI 0.20–0.46) and mental (aOR 0.40, 0.27–0.62) demands in individuals with PCC. Higher age and history of psychiatric diagnosis were associated with more substantial reductions in current work ability. 5.8% of those with PCC reported direct effects of PCC on their occupational situation, with 1.6% of those with PCC completely dropping out of the workforce.

Interpretation These findings highlight the need for providing support and interdisciplinary interventions to individuals affected by PCC to help them maintain or regain their work ability and productivity.

Funding Federal Office of Public Health, Department of Health of the Canton of Zurich, University of Zurich Foundation, Switzerland; Horizon Europe.

Keywords: COVID-19; SARS-CoV-2; Post COVID-19 condition; Long covid; Work; Work ability; Occupation; Cohort; Observational study

Introduction

Post COVID-19 condition (PCC) affects 10–20% of individuals infected with SARS-CoV-2.[1–10] Symptoms associated with PCC are varied and can be physical (such as fatigue, pain, and dyspnoea) or mental (such as memory and concentration difficulties), with a fluctuating course and frequently reported post-exertional exacerbation.[1,2,11,12] Many of these symptoms adversely impact individuals' everyday functioning, including impairments to their ability to engage in physical activities and participate in social life and work.[1,2,13] The prevalence of PCC is highest among those of working age[10,11] and the resulting socioeconomic implications are likely considerable.[14,15] While it is important to develop effective management strategies and interventions to reduce the health burden of PCC, it is thus critical to also consider its impact on the workforce and establish sensible pathways to restore occupational participation in those severely affected.

DOI of original article: https://doi.org/10.1016/j.lanepe.2023.100678
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Research in context

Evidence before this study

We searched PubMed for all articles evaluating the association of post COVID-19 condition (PCC) and work ability and occupational changes, indexed up to 19 April 2023 with no language or time restrictions. The search string '(*"post covid-19" or "long covid" or "pasc" or "post-acute sequelae") and ("work ability" or "occupation*" or "return to work"*)' was used. We screened 311 articles, of which 16 were eligible. Six additional articles were identified through bibliographic searches of relevant articles. Evidence on the association of PCC and work-related outcomes primarily stems from studies that focused on return to work and occupational changes in highly selective populations, such as health care workers, individuals hospitalised for COVID-19, or patients with PCC recruited through post COVID-19 clinics or social media. There was high variability in reported estimates, relating to differences in underlying populations and timepoints of follow-up. Return to work outcomes are highly dependent on systemic and organisational factors, limiting the generalisability of the existing literature. Since perceived work ability is an important determinant of return to work and occupational performance, the Work Ability Index (WAI) provides a validated measure of work-related functioning that is more independent of certain systemic or organisational factors. However, it was only assessed in three studies reporting evidence of reduced work ability in patients with PCC. None assessed risk factors associated with reduced work ability.

Added value of this study

To our knowledge, this is the first study that examined work ability (based on the WAI) and occupational changes and their association with PCC in a population-based cohort of working-age individuals infected with SARS-CoV-2. We found that PCC was strongly associated with a reduction in work ability at one year after infection with a more substantial reduction among older individuals and those with a history of psychiatric diagnosis. We also found that approximately one in fifteen individuals with self-reported COVID-19 related symptoms had occupational changes attributed to PCC within one year, with one to two in 100 completely dropping out of the workforce. This proportion is relevantly lower than reported by others, likely due to non-population-based sampling in other studies, but still constitutes a significant burden on economic and healthcare systems on a global scale.

Implications of all the available evidence

Together with existing evidence, our study suggests that PCC has significant consequences on the workforce. This may have severe implications for affected individuals, employers and the economy. These findings highlight the need to provide timely support and interdisciplinary public health interventions that can support affected individuals in regaining and retaining their work ability.

Several studies have evaluated the association of PCC with work-related functioning or subsequent occupational changes.[16–37] Existing studies were primarily conducted in highly selective populations and mostly focused on describing work absenteeism, showing that 11% up to about half of workers with PCC do not return to work several months after COVID-19.[2,13] Various individual, organisational, and systemic aspects (e.g., supportive return-to-work policies) contribute to successful return to work after an illness, including having sufficient actual work ability.[38–40] Work ability is a multifactorial measure frequently used in clinical practice and research to assess the degree to which an individual is physically and mentally able to cope with demands at work.[41–43] In addition to short- and long-term sickness absence,[44–48] poor work ability is also associated with early retirement[49,50] and disability at work,[50,51] all of which carry large repercussions for the labour market and economy. Rehabilitation programs targeted at the working-age population generally aim to improve or preserve work ability. Given the substantial prevalence of PCC and its potential for long-term work-related consequences, understanding the association of PCC with work ability is crucial for the development of policies and multidisciplinary strategies aimed at supporting affected individuals in their recovery.

In this study, we aimed to comprehensively evaluate the association between PCC, work ability, and occupational changes in a working-age population within a prospective population-based cohort of SARS-CoV-2 infected individuals.

Methods

Study design and participants

We used data from a prospective, population-based, observational cohort of individuals with diagnosed SARS-CoV-2 infection from the Canton of Zurich, Switzerland (Zurich SARS-CoV-2 Cohort; ISRCTN14990068).[5,52] Based on mandatory reporting of all SARS-CoV-2 infections to the Department of Health of the Canton of Zurich, we prospectively invited an age-stratified (18–39 years, 40–64 years, ≥65 years), daily, random sample of eligible individuals diagnosed between 06 August 2020 and 19 January 2021 for study participation. Eligibility criteria were being 18 years or older, able to follow study procedures, residing in the Canton of Zurich, and having sufficient knowledge of the German language. All participants were enrolled upon or shortly after diagnosis,

infected with wildtype SARS-CoV-2, and unvaccinated at time of infection (recruitment took place prior to vaccine rollout in Switzerland). In this study, we included individuals of working age (18–64 years old; retirement age is 65 years in Switzerland) who did not report being retired at enrolment. To ensure that evaluated outcomes were not related to reinfection with SARS-CoV-2 over the course of follow-up, we excluded individuals reporting a reinfection event. The study was approved by the ethics committee of the Canton of Zurich (BASEC-Nr. 2020-01739) and we obtained written or electronic consent from all participants.

Data sources

We collected data using electronic questionnaires. At baseline immediately after enrolment, we collected data on the acute primary infection (i.e., symptoms, severity), pre-existing comorbidities (any of hypertension, diabetes, cardiovascular disease, chronic respiratory disease, chronic kidney disease, malignancy, or immune suppression), pre-infection health status, and sociodemographic characteristics. In this ongoing cohort, we collect follow-up data on participants' health trajectories in regular intervals after infection.[5,52] At the intermediary follow-up time point of 12 months, we additionally elicited measures of work ability and asked participants to report any occupational changes over the first 12 months post-infection. Simultaneously, we asked participants to report any pre-existing psychiatric diagnoses before infection and any new or worsened psychiatric diagnoses during follow-up, as this emerged as an important aspect with respect to PCC over the course of the study.[53] Participants were also asked to provide further details in free text fields. One researcher (DM) additionally conducted personal phone interviews with participants for whom questionnaire information was not unequivocal (n = 4).

Outcome measurement

We assessed self-perceived work ability using selected measures from the Work Ability Index, a validated and frequently used instrument for assessing work ability.[41,42,44] The primary outcome was the current work ability scale (score from 0 to 10, 10 being best ability and 0 no ability to work). In sensitivity analyses, we categorised current work ability into poor (scores ≤6), moderate (scores 7–8), and excellent (scores ≥9).[54] Secondary outcomes included items evaluating work ability related to physical and mental demands (5-point Likert scale) and estimated future work ability in 2 years (3-point Likert scale), as well as occupational changes attributed to PCC by participants during follow-up. Occupational changes attributed to PCC were determined based on a pre-defined list of such potential changes and further information obtained from participants through comments in free text fields or phone interviews (i.e., where no further information on the specific occupational change was provided by the participant or where the relation to SARS-CoV-2 infection was unclear). Further information on evaluated outcomes related to work ability and occupational changes is presented in Supplementary Table S1.

We defined PCC using two different measures to allow better comparability with the heterogenous reporting in other studies and since previous research has shown that the use of multiple definitions allows better evaluation of its impact on affected individuals.[5,55] First, we defined the presence of PCC as participants reporting any COVID-19 related symptom at 12 months of follow-up (*self-reported COVID-19 related symptoms*). This self-reported measure combined the information of two questions, eliciting whether participants experienced any out of a list of 23 symptoms commonly reported to be related to PCC and whether participants deemed these symptoms to be related to COVID-19 (i.e., not to other causes such as pre-existing, chronic, or incident conditions). This definition was as closely aligned with the World Health Organization definition[56] as it was possible in our study. Second, we used a combined measure of whether participants had fully recovered and how they assessed their current health status at 12 months (*(non-)recovery and health impairment*). This self-reported measure combined a question on how participants felt at the time of follow-up compared to before the SARS-CoV-2 infection (fully recovered and symptom-free vs. other responses combined into non-recovered) and the EuroQol visual analogue scale (EQ-VAS); non-recovered participants were categorised into mild (EQ-VAS >70), moderate (EQ-VAS 51–70) and severe health impairment (EQ-VAS ≤50) based on population-normative values from previous research.[5,57–59] Further measures indicating potential presence of PCC were individual self-reported COVID-19 related symptoms, commonly reported PCC-related symptom clusters (fatigue/physical exertion, cardiorespiratory (defined as dyspnoea, palpitation, or chest pain), or neurocognitive (defined as concentration, memory, or sleeping problems)), EuroQol 5-dimension 5-level scale (EQ-5D-5L), Fatigue Assessment Scale (FAS), 21-item Depression, Anxiety and Stress Scale (DASS-21), and modified Medical Research Council (mMRC) dyspnoea scale. Additional details on question wording and categorisation of PCC-related outcomes are provided in Supplementary Table S1.

Sample size

The sample size for this study was determined by the overall sample of individuals enrolled in the cohort. We based the sample size of the overall cohort on the epidemiological situation and expected case numbers at the time of study inception (May 2020). The cohort study had several aims and sample size calculations were adapted to meet the objectives of several research questions of relevance for the public health response to

the pandemic. For this prospective cohort, we determined that a sample size of 1200 would be sufficient to comprehensively evaluate health outcomes over time, allow for pertinent group comparisons, and detect relevant specific health sequelae after infection.[5,52]

Statistical analysis

We descriptively compared the reported work ability outcomes in individuals with self-reported COVID-19 related symptoms or reporting non-recovery with associated level of health impairment 12 months after diagnosis. We further descriptively analysed differences between individuals reporting individual symptoms, symptom clusters, or problems in any of the standardised health assessments (EQ-5D-5L overall and subdomains, FAS, DASS-21, mMRC dyspnoea scale) and those without. We descriptively analysed differences in work ability between participant subgroups based on sex (male vs. female), age (40–64 years vs. 18–39 years), comorbidity count (0–1 comorbidity vs. ≥2 comorbidities), and history of psychiatric diagnosis (present vs. absent), and based on the occurrence of new or worsened psychiatric diagnoses. Furthermore, we described the occupational changes experienced by participants overall and specifically attributed to PCC.

We used univariable and multivariable regression models to evaluate the association of PCC-related outcomes with work ability outcomes. Model selection included age, sex, baseline health status, hospitalisation during acute infection as a priori covariates, with education level, comorbidity count, and history of psychiatric diagnosis added based on improved model fit using the Bayesian Information criterion (BIC; 2-point change considered relevant). We carefully examined all respective model assumptions, which were reasonably met. For current work ability (scores 0–10), we used linear regression in primary analyses to allow interpretation in terms of mean score differences and ordinal logistic regression in sensitivity analyses. We used ordinal logistic regression for Likert scale-based work ability outcomes. Correspondingly, we report adjusted linear model estimates (score differences) and adjusted odds ratios (aORs) with corresponding 95% confidence intervals (CIs). Unadjusted (crude) model results are provided in the Supplementary Material. We evaluated differences in the strength of associations (i.e., effect modification) between participant subgroups (as defined above) by using interaction models.

We assumed missing data arising from non-response or loss to follow-up to be missing at random and excluded corresponding observations from the analyses. We based our reporting on the framework of the strength of statistical evidence (using levels ranging from weak to very strong evidence) instead of applying a single threshold to determine significance.[60,61] We did not adjust p-values for multiple testing to facilitate the interpretation of our results based on this framework. We performed all statistical analyses using R (v4.2.2).

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

In the Zurich SARS-CoV-2 Cohort, 3185 individuals were randomly sampled and invited in the study by the Department of Health of the Canton of Zurich, 1294 agreed to being contacted by the study team, and 1106 consented for participation (participation rate 34.7%; Supplementary Fig. S1). 306 of 1106 cohort participants were not part of the working-age population, 15 were excluded due to reinfection, and 113 did not provide data at 12 months. Of 672 participants included in this study, 364 (54.2%) were female, 390 (58.0%) were aged 40–64 years, 79 (11.8%) were asymptomatic, and 9 (1.3%) were hospitalised at initial infection (Table 1). 19 participants (2.8%) reported being unemployed and 4 (0.6%) reported receiving disability insurance benefits at baseline. With respect to PCC, 120 of 672 (17.9%) participants reported having COVID-19 related symptoms, and 93 of 655 (14.2%; data on EQ-VAS missing for 7 individuals) reported not having recovered at 12 months, with mild (N = 72, 11.0%), moderate (N = 13, 2.0%), and severe health impairment (N = 8, 1.2%), respectively. There were differences in age, sex, severity of acute infection, comorbidities, and history of psychiatric diagnoses between those categorised as having PCC and those without.

In descriptive analyses of current work ability, ability related to physical and mental demands at work, and estimated future work ability in 2 years, there was a relevant reduction in work ability across all four outcomes among those reporting COVID-19 related symptoms compared to those without and among those reporting non-recovery compared to those that had recovered at 12 months (Fig. 1 and Supplementary Table S2). Work ability among those reporting non-recovery was more strongly reduced in those with moderate and severe health impairment compared to those with mild health impairment.

In adjusted regression analyses, there was very strong evidence that current work ability scores were mean 0.62 (95% CI 0.30–0.95; p = 0.0002) points lower among those reporting COVID-19 related symptoms compared to those without (Fig. 2 and Supplementary Tables S3–S6). Current work ability scores were mean 0.55 (0.21–0.88, p = 0.0016), 3.37 (2.58–4.16, p < 0.0001), and 5.10 (4.16–6.04, p < 0.0001) points lower among those with non-recovery and mild, moderate, and severe health impairment, respectively, compared to those reporting full recovery (very strong

	Self-reported COVID-19 related symptoms		(Non-) recovery and health impairment				Overall
	No symptoms	Symptoms	Recovered	Mild	Moderate	Severe	
	(N = 552)	(N = 120)	(N = 562)	(N = 72)	(N = 13)	(N = 8)	(N = 672)
Age (years)							
Mean (SD)	41.1 (12.2)	46.6 (10.9)	41.2 (12.2)	46.0 (11.4)	49.2 (8.8)	49.5 (12.8)	42.1 (12.2)
Median (IQR)	41.0 (30.8–51.2)	50.0 (38.0–55.0)	41.5 (30.0–51.8)	48.0 (35.8–55.2)	51.0 (45.0–56.0)	53.0 (45.0–58.0)	43.0 (31.0–53.0)
Range	18–63	21–62	18–63	25–62	32–59	24–62	18–63
Age group							
18–39 years	249 (45.1%)	33 (27.5%)	250 (44.5%)	22 (30.6%)	3 (23.1%)	2 (25.0%)	282 (42.0%)
40–64 years	303 (54.9%)	87 (72.5%)	312 (55.5%)	50 (69.4%)	10 (76.9%)	6 (75.0%)	390 (58.0%)
Sex							
Female	285 (51.6%)	79 (65.8%)	292 (52.0%)	47 (65.3%)	11 (84.6%)	6 (75.0%)	364 (54.2%)
Male	267 (48.4%)	41 (34.2%)	270 (48.0%)	25 (34.7%)	2 (15.4%)	2 (25.0%)	308 (45.8%)
Symptom count at infection							
Asymptomatic	67 (12.1%)	12 (10.0%)	70 (12.5%)	5 (6.9%)	1 (7.7%)	1 (12.5%)	79 (11.8%)
1–5 symptoms	233 (42.2%)	33 (27.5%)	230 (40.9%)	25 (34.7%)	1 (7.7%)	3 (37.5%)	266 (39.6%)
≥6 symptoms	252 (45.7%)	75 (62.5%)	262 (46.6%)	42 (58.3%)	11 (84.6%)	4 (50.0%)	327 (48.7%)
Hospitalisation at infection							
Non-hospitalised	547 (99.1%)	115 (95.8%)	559 (99.5%)	69 (95.8%)	11 (84.6%)	7 (87.5%)	662 (98.5%)
Hospitalised	5 (0.9%)	5 (4.2%)	3 (0.5%)	3 (4.2%)	2 (15.4%)	1 (12.5%)	10 (1.5%)
with ICU stay	0 (0.0%)	1 (0.8%)	0 (0.0%)	0 (0.0%)	1 (7.7%)	0 (0.0%)	1 (0.1%)
Smoking status							
Non-smoker	343 (62.4%)	70 (58.3%)	347 (62.0%)	42 (58.3%)	9 (69.2%)	6 (75.0%)	413 (61.6%)
Ex-smoker	123 (22.4%)	33 (27.5%)	127 (22.7%)	20 (27.8%)	2 (15.4%)	1 (12.5%)	156 (23.3%)
Smoker	84 (15.3%)	17 (14.2%)	86 (15.4%)	10 (13.9%)	2 (15.4%)	1 (12.5%)	101 (15.1%)
Missing	*2 (0.4%)*	*0 (0%)*	*2 (0.4%)*	*0 (0%)*	*0 (0%)*	*0 (0%)*	*2 (0.3%)*
BMI (kg/sqm)							
Mean (SD)	24.2 (4.3)	25.6 (5.1)	24.3 (4.3)	24.9 (4.7)	29.9 (7.5)	22.4 (1.9)	24.4 (4.5)
Median (IQR)	23.6 (21.5–25.9)	24.8 (22.1–28.6)	23.6 (21.5–26.0)	24.5 (21.7–27.0)	30.4 (26.0–31.1)	22.3 (20.7–23.7)	23.7 (21.5–26.2)
Range	13–63	17–45	17–63	18–40	20–45	20–25	13–63
Missing	*5 (0.9%)*	*1 (0.8%)*	*6 (1.1%)*	*0 (0%)*	*0 (0%)*	*0 (0%)*	*6 (0.9%)*
Comorbidity[a]							
None	453 (82.1%)	79 (65.8%)	460 (81.9%)	49 (68.1%)	6 (46.2%)	4 (50.0%)	532 (79.2%)
1 comorbidity	80 (14.5%)	33 (27.5%)	85 (15.1%)	18 (25.0%)	5 (38.5%)	3 (37.5%)	113 (16.8%)
≥2 comorbidities	19 (3.4%)	8 (6.7%)	17 (3.0%)	5 (6.9%)	2 (15.4%)	1 (12.5%)	27 (4.0%)
Comorbidity count[a]							
Median (IQR)	0 (0–0)	0 (0–1)	0 (0–0)	0 (0–1)	1 (0–1)	0.5 (0–1)	0 (0–0)
Range	0–3	0–2	0–3	0–2	0–2	0–2	0–3
History of psychiatric diagnosis							
None	472 (88.6%)	93 (78.8%)	486 (87.7%)	63 (87.5%)	6 (50.0%)	5 (62.5%)	565 (86.8%)
Any	61 (11.4%)	25 (21.2%)	68 (12.3%)	9 (12.5%)	6 (50.0%)	3 (37.5%)	86 (13.2%)
Depression	27 (4.9%)	18 (15.0%)	32 (5.7%)	5 (6.9%)	5 (38.5%)	3 (37.5%)	45 (6.7%)
Anxiety	12 (2.2%)	2 (1.7%)	13 (2.3%)	0 (0.0%)	0 (0.0%)	1 (12.5%)	14 (2.1%)
Burnout	6 (1.1%)	3 (2.5%)	6 (1.1%)	1 (1.4%)	2 (15.4%)	0 (0.0%)	9 (1.3%)
Bipolar disorder	2 (0.4%)	0 (0.0%)	2 (0.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.3%)
ADHD	2 (0.4%)	1 (0.8%)	2 (0.4%)	1 (1.4%)	0 (0.0%)	0 (0.0%)	3 (0.4%)
PTSD	4 (0.7%)	1 (0.8%)	4 (0.7%)	0 (0.0%)	0 (0.0%)	1 (12.5%)	5 (0.7%)
Eating disorder	1 (0.2%)	1 (0.8%)	2 (0.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.3%)
Sleep disorder	2 (0.4%)	0 (0.0%)	2 (0.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.3%)
Other	2 (0.4%)	0 (0.0%)	2 (0.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.3%)
Missing	*19 (3.4%)*	*2 (1.7%)*	*8 (1.4%)*	*0 (0%)*	*1 (7.7%)*	*0 (0%)*	*21 (3.1%)*

(Table 1 continues on next page)

	Self-reported COVID-19 related symptoms		(Non-) recovery and health impairment				Overall
	No symptoms	Symptoms	Recovered	Mild	Moderate	Severe	
	(N = 552)	(N = 120)	(N = 562)	(N = 72)	(N = 13)	(N = 8)	(N = 672)
(Continued from previous page)							
Education level							
None or mandatory school	17 (3.1%)	5 (4.2%)	16 (2.9%)	4 (5.6%)	0 (0.0%)	0 (0.0%)	22 (3.3%)
Vocational training or specialised baccalaureate	194 (35.1%)	55 (46.6%)	199 (35.5%)	33 (46.5%)	7 (53.8%)	3 (37.5%)	249 (37.2%)
Higher technical school or college	165 (29.9%)	29 (24.6%)	173 (30.8%)	16 (22.5%)	2 (15.4%)	2 (25.0%)	194 (29.0%)
University	176 (31.9%)	29 (24.6%)	173 (30.8%)	18 (25.4%)	4 (30.8%)	3 (37.5%)	205 (30.6%)
Missing	0 (0%)	2 (1.7%)	1 (0.2%)	1 (1.4%)	0 (0%)	0 (0%)	2 (0.3%)
Employment at infection							
Employed or self-employed	488 (88.4%)	99 (82.5%)	494 (87.9%)	61 (84.7%)	11 (84.6%)	4 (50.0%)	587 (87.4%)
Student	42 (7.6%)	4 (3.3%)	45 (8.0%)	1 (1.4%)	0 (0.0%)	0 (0.0%)	46 (6.8%)
Housewife/family manager	9 (1.6%)	1 (0.8%)	9 (1.6%)	1 (1.4%)	0 (0.0%)	0 (0.0%)	10 (1.5%)
Unemployed	9 (1.6%)	10 (8.3%)	10 (1.8%)	7 (9.7%)	1 (7.7%)	1 (12.5%)	19 (2.8%)
Disability insurance benefits	0 (0.0%)	4 (3.3%)	0 (0.0%)	0 (0.0%)	1 (7.7%)	3 (37.5%)	4 (0.6%)
Other	4 (0.7%)	2 (1.7%)	4 (0.7%)	2 (2.8%)	0 (0.0%)	0 (0.0%)	6 (0.9%)
Income							
<6′000 CHF	149 (28.0%)	40 (34.8%)	156 (28.7%)	23 (32.9%)	3 (25.0%)	4 (50.0%)	189 (29.2%)
6′000–12′000 CHF	231 (43.3%)	52 (45.2%)	234 (43.1%)	33 (47.1%)	7 (58.3%)	1 (12.5%)	283 (43.7%)
>12′000 CHF	153 (28.7%)	23 (20.0%)	153 (28.2%)	14 (20.0%)	2 (16.7%)	3 (37.5%)	176 (27.2%)
Missing	19 (3.4%)	5 (4.2%)	19 (3.4%)	2 (2.8%)	1 (7.7%)	0 (0%)	24 (3.6%)
Nationality							
Swiss	465 (84.2%)	97 (80.8%)	479 (85.2%)	56 (77.8%)	9 (69.2%)	7 (87.5%)	562 (83.6%)
Non-Swiss	87 (15.8%)	23 (19.2%)	83 (14.8%)	16 (22.2%)	4 (30.8%)	1 (12.5%)	110 (16.4%)

ADHD, attention deficit hyperactivity disorder; BMI, body mass index; CHF, Swiss Francs; ICU, intensive care unit; IQR, interquartile range; PTSD, post-traumatic stress disorder; SD, standard deviation.
[a]Comorbidities were assessed as any of the following: hypertension, diabetes, cardiovascular disease, chronic respiratory disease, chronic kidney disease, past or present malignancy, or immune suppression.

Table 1: **Detailed study population characteristics, stratified by the presence of self-reported COVID-19 related symptoms and (non-)recovery and health impairment at 12 months after diagnosis of primary infection.**

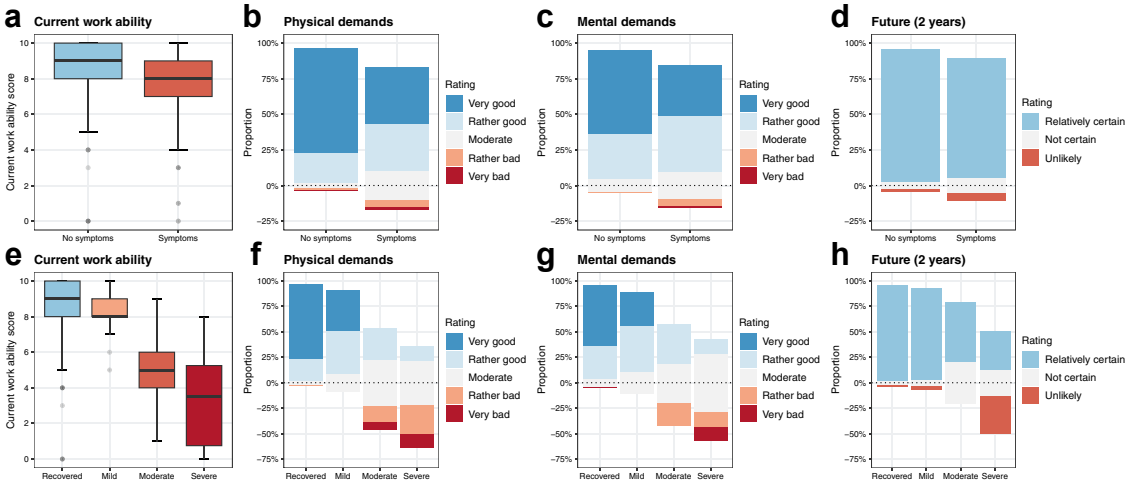

Fig. 1: **Current work ability, work ability related to physical and mental demands, and estimated future work ability in 2 years by presence of self-reported COVID-19 related symptoms and (non-)recovery and health impairment at 12 months after diagnosis of primary infection.** Panels a–d demonstrate the level of current work ability (a), work ability related to physical (b) and mental (c) demands, and estimated work ability in 2 years (d) between individuals with self-reported COVID-19 related symptoms at 12 months compared to those without symptoms. Panels e–h show the level of current work ability (e), work ability related to physical (f) and mental (g) demands, and estimated work ability in 2 years (h) between individuals reporting non-recovery with mild, moderate, or severe health impairment at 12 months compared to those reporting full recovery at 12 months.

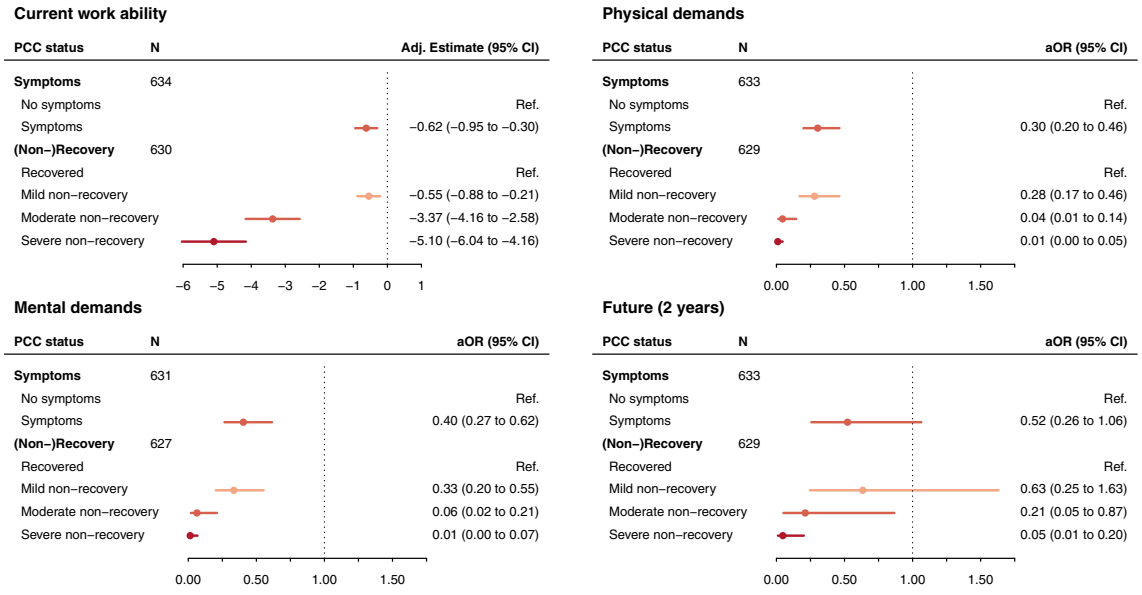

Fig. 2: **Results from multivariable regression analyses of the association between presence of post COVID-19 condition (defined as presence of self-reported COVID-19 related symptoms and (non-)recovery and health impairment) and current work ability, work ability related to physical and mental demands, and estimated future work ability in 2 years at 12 months after diagnosis of primary infection.** Each panel demonstrates results from multivariable linear regression (current work ability) or ordinal logistic regression (work ability related to physical and mental demands, estimated work ability in future) adjusted for sex, age, education level, baseline EuroQol visual analogue scale (EQ-VAS), comorbidity count, history of psychiatric diagnosis, and hospitalisation at acute infection. Separate models were estimated for the two definitions of post COVID-19 condition based on self-reported COVID-19 related symptoms (symptoms vs. no symptoms) and (non-) recovery and health impairment (severe, moderate or mild health impairment vs. recovery). Legend: CI, confidence interval; OR, odds ratio; PCC, post COVID-19 condition; Ref., reference.

evidence). Similarly, there was very strong evidence for a lower odds of having higher work ability with respect to physical (aOR 0.30, 95% CI 0.20–0.46, p < 0.0001) and mental (aOR 0.40, 0.27–0.62, p < 0.0001) demands among those reporting COVID-19 related symptoms compared to those without. Results were similar when evaluating non-recovered individuals compared to those reporting recovery, while reductions in work ability were more pronounced with higher levels of health impairment. There was no evidence for lower odds of having higher estimated future work ability in 2 years (aOR 0.52, 0.26–1.06, p = 0.074) among those reporting COVID-19 related symptoms compared to those without and among those with non-recovery and mild health impairment compared to those reporting recovery, but strong evidence for a reduction in those with moderate or severe health impairment compared to recovered participants. Sensitivity analyses treating current work ability as an ordinal outcome showed similar results (Supplementary Fig. S2 and Table S7).

Further analyses demonstrate the association between the presence of specific symptom clusters (i.e., fatigue/physical exertion, cardiorespiratory, and neurocognitive symptoms), individual self-reported COVID-19 related symptoms, and presence of health problems in scale-based outcomes (EQ-5D-5L, FAS, DASS-21, and mMRC dyspnoea scale) and work ability outcomes at 12 months (Supplementary Fig. S3–S5 and Tables S8–S18). There was very strong evidence for an association between PCC-related symptom clusters and current work ability, as well as work ability related to physical and mental demands. Meanwhile, there was evidence for an association between some, but not all individual self-reported COVID-19 related symptoms and work ability outcomes. There was very strong evidence for an association between problems on any of the scale-based outcomes and current work ability, as well as work ability related to physical and mental demands.

In subgroup analyses, there was strong evidence for a difference in the association (i.e., effect modification) of the presence of self-reported COVID-19 related symptoms with current work ability and work ability related to physical demands between participants aged 40–64 years and those aged 18–39 years, with a higher reduction in work ability in the older group (Table 2, Supplementary Tables S19–S23). Meanwhile, there was no evidence for a difference in the association of self-reported COVID-19 related symptoms with any work ability outcome between male and female participants, or between participants with 0–1 comorbidity and participants with ≥2 comorbidities. Last, there was a stronger association of self-reported COVID-19 related

Interaction	Current work ability			Physical demands			Mental demands			Future (2 years)		
	N	Adj. Estimate (95% CI)	p-value	N	aOR (95% CI)	p-value	N	aOR (95% CI)	p-value	N	aOR (95% CI)	p-value
Male vs. female	634			633			631			633		
Female		−0.82 (−1.23 to −0.42)	<0.0001		0.37 (0.22–0.62)	0.0002		0.40 (0.23–0.67)	0.0006		0.54 (0.23–1.27)	0.16
Male		−0.30 (−0.81 to 0.21)	0.25		0.22 (0.11–0.43)	<0.0001		0.42 (0.22–0.81)	0.0092		0.48 (0.14–1.64)	0.24
Difference[a]		*0.53 (−0.12 to 1.17)*	*0.11*		*0.60 (0.26–1.38)*	*0.23*		*1.06 (0.46–2.42)*	*0.89*		*0.89 (0.21–3.88)*	*0.88*
40–64 years vs. 18–39 years	634			633			631			633		
18–39 years		−0.27 (−0.86 to 0.32)	0.37		0.74 (0.33–1.65)	0.46		0.69 (0.33–1.44)	0.32		0.93 (0.19–4.45)	0.92
40–64 years		−0.78 (−1.16 to −0.40)	<0.0001		0.20 (0.12–0.34)	<0.0001		0.33 (0.20–0.55)	<0.0001		0.43 (0.19–0.96)	0.040
Difference[a]		*−0.51 (−1.20 to 0.19)*	*0.15*		*0.27 (0.11–0.71)*	*0.0064*		*0.48 (0.20–1.17)*	*0.11*		*0.46 (0.08–2.67)*	*0.37*
≥2 comorbidities vs. 0–1 comorbidity[b]	634			633			631			633		
0–1 comorbidity		−0.64 (−0.97 to −0.31)	0.0001		0.31 (0.20–0.47)	<0.0001		0.39 (0.26–0.60)	<0.0001		0.46 (0.22–0.96)	0.040
≥2 comorbidities		−0.92 (−2.34 to 0.50)	0.20		0.10 (0.01–0.79)	0.028		0.52 (0.08–3.34)	0.49		1.19 (0.10–14.80)	0.89
Difference[a]		*−0.28 (−1.74 to 1.18)*	*0.70*		*0.34 (0.04–2.67)*	*0.31*		*1.32 (0.20–8.90)*	*0.78*		*2.59 (0.19–36.17)*	*0.46*
History of psychiatric diagnosis vs. no history of psychiatric diagnosis	634			633			631			633		
No history of psychiatric diagnosis		−0.39 (−0.74 to −0.04)	0.031		0.28 (0.17–0.44)	<0.0001		0.35 (0.22–0.55)	<0.0001		0.49 (0.22–1.08)	0.077
History of psychiatric diagnosis		−1.73 (−2.47 to −0.99)	<0.0001		0.49 (0.18–1.31)	0.15		0.88 (0.33–2.35)	0.80		0.65 (0.15–2.76)	0.56
Difference[a]		*−1.34 (−2.15 to −0.54)*	*0.0010*		*1.76 (0.60–5.17)*	*0.30*		*2.55 (0.88–7.38)*	*0.086*		*1.33 (0.27–6.67)*	*0.72*

Adj., adjusted; CI, confidence interval; aOR, adjusted odds ratio. [a]Differences are interpreted as the difference in adjusted mean score differences (current work ability) or adjusted odds ratios (work ability related to physical and mental demands, estimated future work ability in 2 years) for the comparison between individuals with self-reported COVID-19 related symptoms compared with those without symptoms, quantifying the extent of effect modification for the respective stratification variable. P-values for differences were calculated using likelihood ratio tests for models with and without interaction term for the respective stratification variable. We used multivariable linear regression models (current work ability) and multivariable ordinal logistic regression models (work ability related to physical and mental demands, estimated future work ability in 2 years) including an interaction term for the respective stratification variable and adjusted for age (or age group for the corresponding analysis), sex, education status, baseline EuroQol visual analogue scale (EQ-VAS), comorbidity count (as a continuous variable, or as a dichotomous categorical variable for the corresponding analysis), history of psychiatric diagnosis, and hospitalisation due to COVID-19. [b]Comorbidities were assessed as any of the following: hypertension, diabetes, cardiovascular disease, chronic respiratory disease, chronic kidney disease, past or present malignancy, or immune suppression.

Table 2: **Results from multivariable regression analyses for the association of the presence of self-reported COVID-19 related symptoms with work ability outcomes at 12 months after diagnosis of primary infection (symptoms vs. no symptoms) within subgroups based on sex, age group, comorbidity count, or history of psychiatric diagnosis.**

symptoms with current work ability and work ability related to mental demands in participants with history of psychiatric diagnosis compared to those without. Further descriptive analyses demonstrated relevant differences between participants with different mental health trajectories, indicating a stronger reduction in work ability among participants with history of psychiatric diagnosis and those with a new or worsened psychiatric diagnosis compared to those without history or new or worsened diagnosis, respectively (Supplementary Table S24).

When evaluating occupational changes up to 12 months, overall 119 (18.1%) participants reported to have had such a change during follow-up (Table 3), with a slightly higher proportion among participants reporting COVID-19 related symptoms (31/120, 25.8%) compared to those without such symptoms (88/552, 16.3%). 7 participants (1.1% of all participants, 5.8% of those with self-reported COVID-19 related symptoms) reported to have faced direct effects by PCC on their occupational situation. Work ability at 12 months was relevantly reduced among those 7 participants with occupational changes attributed to PCC compared to those without occupational changes and those with PCC-unrelated occupational changes (Supplementary Table S25).

The 7 participants with occupational changes attributed to PCC reported various individual stories in how PCC affected their work life. One participant lost their work due to PCC. Another reported to be on permanent sick leave at 12 months and being severely affected in daily life. One participant reported that they were unemployed at baseline and could not take on a new position due to PCC, and one was in a job re-integration program but was unable to re-enter the job market due to PCC. Another participant was so severely impacted cognitively that they could no longer use their professional skills (university level) and had to switch to doing simple administrative tasks. One health care worker reported that they had to take a different position that did not require working night shifts. And one participant reported that they had to discontinue their self-employed work as an instructor and seek another part-time job to cope financially because of PCC. Overall, 3 participants (43%) with PCC-attributed occupational changes reported to have some financial difficulties as a result of their condition and their resulting occupational situation.

	Self-reported COVID-19 related symptoms		(Non-)recovery and health impairment				Overall
	No symptoms	Symptoms	Recovered	Mild	Moderate	Severe	
	(N = 552)	(N = 120)	(N = 562)	(N = 72)	(N = 13)	(N = 8)	(N = 672)
Occupational change							
No occupational change	451 (83.7%)	89 (74.2%)	468 (83.9%)	58 (80.6%)	6 (46.2%)	3 (37.5%)	540 (81.9%)
Occupational change unrelated to PCC	88 (16.3%)	24 (20.0%)	90 (16.1%)	13 (18.1%)	4 (30.8%)	3 (37.5%)	112 (17.0%)
Occupational change attributed to PCC	0 (0.0%)	7 (5.8%)	0 (0.0%)	1 (1.4%)	3 (23.1%)	2 (25.0%)	7 (1.1%)
Missing	*13 (2.4%)*	*0 (0%)*	*4 (0.7%)*	*0 (0%)*	*0 (0%)*	*0 (0%)*	*13 (1.9%)*
Reason for occupational change[a]							
Retired	4 (4.6%)	2 (6.5%)	5 (5.6%)	0 (0.0%)	0 (0.0%)	1 (20.0%)	6 (5.1%)
On permanent sick leave	3 (3.4%)	1 (3.2%)	2 (2.2%)	0 (0.0%)	1 (14.3%)	0 (0.0%)	4 (3.4%)
Receiving disability benefits	0 (0.0%)	1 (3.2%)	0 (0.0%)	0 (0.0%)	1 (14.3%)	0 (0.0%)	1 (0.8%)
Work leave for different reason	3 (3.4%)	0 (0.0%)	3 (3.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (2.5%)
Newly self-employed	2 (2.3%)	0 (0.0%)	2 (2.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (1.7%)
Changed workplace	42 (48.3%)	14 (45.2%)	46 (51.7%)	7 (50.0%)	3 (42.9%)	0 (0.0%)	56 (47.5%)
Changed position within same workplace	13 (14.9%)	4 (12.9%)	11 (12.4%)	4 (28.6%)	0 (0.0%)	1 (20.0%)	17 (14.4%)
Started training or university studies	5 (5.7%)	0 (0.0%)	4 (4.5%)	1 (7.1%)	0 (0.0%)	0 (0.0%)	5 (4.2%)
Reduced working hours	2 (2.3%)	0 (0.0%)	2 (2.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (1.7%)
Lost employment	4 (4.6%)	2 (6.5%)	5 (5.6%)	0 (0.0%)	1 (14.3%)	0 (0.0%)	6 (5.1%)
Other	9 (10.3%)	7 (22.6%)	9 (10.1%)	2 (14.3%)	1 (14.3%)	3 (60.0%)	16 (13.6%)
Missing	*1 (1.1%)*	*0 (0%)*	*1 (1.1%)*	*0 (0%)*	*0 (0%)*	*0 (0%)*	*1 (0.8%)*
Financial difficulties due to occupational change[a]							
No	57 (64.8%)	17 (54.8%)	56 (62.2%)	10 (71.4%)	4 (57.1%)	3 (60.0%)	74 (62.2%)
Rather not	12 (13.6%)	6 (19.4%)	15 (16.7%)	3 (21.4%)	0 (0.0%)	0 (0.0%)	18 (15.1%)
Yes, a little	14 (15.9%)	7 (22.6%)	15 (16.7%)	1 (7.1%)	3 (42.9%)	1 (20.0%)	21 (17.6%)
Yes, very much	5 (5.7%)	0 (0.0%)	4 (4.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (4.2%)
Unclear/no answer	0 (0.0%)	1 (3.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (20.0%)	1 (0.8%)

PCC, post COVID-19 condition. [a]Percentages calculated within total of individuals with any occupational change (N = 119).

***Table 3*: Occupational changes related to post COVID-19 condition and overall, stratified by presence of self-reported COVID-19 related symptoms and (non-)recovery and health impairment at 12 months after diagnosis of primary infection.**

Discussion

In this prospective population-based cohort of working-age individuals previously infected with SARS-CoV-2, we found that the presence of self-reported COVID-19 related symptoms was strongly associated with a reduction in work ability at 12 months after diagnosis. Among non-recovered, higher levels of health impairment were also associated with substantially lower current work ability and work ability related to physical and mental demands. We found strong evidence that higher age and a history of psychiatric diagnosis was associated with a stronger reduction in current work ability. About 1 in 15 of those with self-reported COVID-19 related symptoms reported having had occupational changes attributed to PCC within one year, with 1.6% completely dropping out of the workforce.

Evidence on the impact of PCC on the occupational situation and work-related impairments is limited and heterogenous.[16–21,23–30,32,34–37] Prior studies have primarily evaluated specific populations, such as PCC-affected individuals recruited through specialised post COVID-19 clinics[18,23,27,29,32,35,36] or social media,[19,20,25,28,34,37] hospitalised COVID-19 patients,[16,21,26,29] or healthcare workers,[24,31] resulting in limited generalisability. They have reported that between 11% and 52% of affected individuals do not return to work[16,18–20,25–30,34,35,37] and that 10%–72% do not fully regain their work capacity 6–12 months after infection.[19,21,23,25,27,31,32,34,36,37] We estimated this proportion to be 5.8% after one year, which is relevantly lower than reported in other studies. This is likely explained by differences in the evaluated populations and assessment time points (only few studies had a follow-up of six months or longer). Differences between countries in terms of sickness and disability benefits systems, as well as cultural and organisational factors, may also explain the wide range of estimates in the literature. Nevertheless, the impact of PCC on the working-age population appears to be substantial and will likely lead to long-term burdens on economic and healthcare systems.

An important factor that determines sustainable return to work is the perceived work ability, which is also more independent of the specific context than return to work and occupational changes. To date, few studies

have evaluated work ability in the context of PCC, which were also conducted within selective populations.[22,31,33] Evidence from these studies and our study demonstrated lower work ability scores among those with PCC, with a higher reduction among those with occupational changes. However, it is important to note that although most of the participants with PCC did not have occupational changes and remained at work, decreased work ability in this group may still indicate reduced productivity and efficiency. Sickness presenteeism (i.e., continuing to work while sick) may have negative effects on both the individuals and their employers.[62] Sick employees usually need extra efforts to cope with job demands which may lead to additional worsening of their health, and the costs of having a sick employee are estimated to be the same as or even higher than their actual absence.[62] Strategies that improve work-related capacity in individuals affected by PCC and promote return to work are urgently needed. In addition, since reduced work ability also is a predictor of early retirement,[49,50] it will be vital in the coming years to continuously monitor whether there are increases in the number of people retiring early due to PCC.

We found a more substantial decrease in current work ability among individuals aged 40–64 years compared to younger individuals. This is concerning since the middle-aged population is typically viewed as the foundation of most economies, as they account for a significant proportion of the workforce, tax revenue, and gross domestic product. We also found that individuals with a history of psychiatric diagnosis had a greater reduction in work ability than those without. The relationship between work and mental health is well-established in the literature.[40,63] Similarly, the association of pre-existing psychiatric disorders with PCC has also been demonstrated in several studies, with evidence of a higher risk of PCC among those with anxiety or depression prior to infection.[53,64] Effectively, such conditions may simultaneously be a risk factor for the development of PCC (if pre-existing),[53,64] part of the broader symptom complex of PCC,[1,2] or a consequence of other (non-psychiatric) PCC-related symptoms,[65] which are difficult to separate. Targeted strategies and support measures from occupational and rehabilitation medicine, possibly leveraging pre-existing programs for individuals with chronic illnesses, should be put in place to support individuals affected by PCC. In addition, both employees and employers need to be made aware of the mental health aspects of PCC and the impact of mental health on work, as health-promoting working conditions and, for example, supportive leadership may be relevant to the re-integration of relevant subgroups of employees.[66]

Fallout from reduced work capacity results not only in financial and health challenges for individuals affected by PCC, but can also have substantial consequences for public health and the economy and society in the longer term. Altogether, our findings underline the necessity for interdisciplinary interventions aimed at individuals affected by PCC, including those with moderate or even mild health impairment. Given that early intervention is a core principle of occupational rehabilitation, further research is warranted to determine whether earlier rehabilitation could improve work outcomes in people with persistent symptoms after COVID-19 but who are not yet diagnosed with PCC. Identifying specific COVID-19 symptoms that predict impairment in work ability will help to develop and provide such early interventions. From this perspective, it will also be crucial to determine what size of reduction in the work ability of affected individuals can be considered relevant (i.e., minimal important difference) for the context of PCC, which will aid in the design and interpretation of trials evaluating rehabilitation measures.

Strengths of the study include its population-based approach, the recruitment of participants at or shortly after diagnosis during a time period when PCC was not yet a concern, the large sample size, and the high retention rate at one year (90%) limiting emigrative selection bias arising from loss to follow-up. In addition, the granularity of the data and the use of a validated, internationally used, and context-independent measure of work ability strengthens our evaluation. However, some limitations need to be considered. First, the participation rate was relatively low (35%). Immigrative selection may have occurred if individuals who were more health literate were more likely to participate or if individuals who had PCC and were more severely impacted were also more likely to be retained in the study. This may have led to an overestimation of the association between PCC and work ability. We previously evaluated differences between cohort participants and individuals not participating in our study and found that those in our study were less likely to be hospitalised and younger on average.[5] This may have biased our findings towards lower estimates. Hence, the direction of any potential bias is unclear. Second, the relatively low proportion of hospitalised participants limits the generalisability of our results to those with the most severe acute disease, who may also suffer from more severe medical complications and sequelae of the hospital stay (e.g., post intensive care syndrome). Additionally, the generalisability of our findings to individuals infected with emerging SARS-CoV-2 variants of concern or who were vaccinated prior to infection is limited, since our participants were all infected with wildtype SARS-CoV-2 and unvaccinated at infection. The risk of PCC and severe health impairment is substantially reduced with vaccination and infection with newer variants, but still present.[67–70] As the impact of PCC on work ability is likely comparable in these contexts, this may have significant socioeconomic implications given that more than 45% of the global population

is estimated to have been infected with the Omicron variant.[71] Further research is needed to evaluate whether similar reduced work ability and occupational changes are observed in vaccinated populations and in the context of emerging variants of concern. Nonetheless, the population from the early stages of the pandemic included in this study remains highly relevant since these are the individuals experiencing long-term health consequences at present, posing a challenge to public health. Third, we assessed PCC using self-reported measures. Since we could not conduct a clinical validation of PCC (i.e., assess whether self-reported COVID-19 related symptoms or reported health impairment were indeed attributable to SARS-CoV-2 infection), we cannot fully exclude that reported symptoms and health impairment were related to the presence or worsening of pre-existing or incident conditions or other infections. Yet, we consider self-reported measures key in capturing the lived experience of those affected. Our study was not designed to fully capture all possible fluctuations or relapses of symptoms during follow-up. However, the comparable results across two different definitions of PCC and our previous findings of a higher prevalence of several symptoms among Zurich SARS-CoV-2 Cohort participants compared to an uninfected sample from the general population further strengthen the credibility of our findings.[5] Fourth, multiple hypothesis tests were conducted in association analyses within this study, which may have resulted in spurious (false positive) findings. Fifth, we did not have data on participants' work ability prior to SARS-CoV-2 infection or on work-related outcomes in a comparable non-infected group. Thus, we could not evaluate changes in work ability scores from before infection and whether these met a minimal important difference threshold. We also cannot be fully certain that the reduced work ability or occupational changes are entirely due to SARS-CoV-2 infection and not other causes, such as pre-existing or incident conditions or other effects of the pandemic. While we at least partially accounted for the lack of work-related information prior to infection by adjusting for baseline health status in our models, this may not have fully resolved this issue. However, work ability scores among those categorised as not having PCC in our study were broadly comparable with estimates from the Swedish general population in 2017, while scores among those affected by PCC were lower (Supplementary Table S26).[48] In addition, the detailed evaluation of the participants' individual stories supports our finding of a reduced work ability related to PCC. In contrast, since we relied on participants' self-reporting of occupational changes related to SARS-CoV-2 infection, it is possible that we did not capture all changes attributable to PCC if they were not perceived or reported as such by participants. This may have resulted in an underestimation of the proportion with PCC-attributable occupational changes.

In conclusion, this population-based study found that the presence of PCC was associated with a reduction in work ability one year after SARS-CoV-2 infection and led to an inability to work in some of the infected individuals. Such reductions in productivity and work capacity can have severe implications for individuals, families, and society as a whole. It is critical that policymakers, healthcare professionals, and employers recognise the impact of PCC on the workforce and develop effective strategies and interventions that can support and enable affected individuals in regaining and retaining their work ability.

Contributors

TB, DM, JSF, and MAP conceived and planned the Zurich SARS-CoV-2 Cohort study. TB, DM, and MAP coordinated the Zurich SARS-CoV-2 Cohort study. PK, TB, MAP, and DM conceived and planned this analysis. TB, DM, AD, and MAP contributed to participant recruitment and data collection. MAP supervised the project. JSF and MAP obtained funding. TB and DM accessed and verified the data and prepared the analytic datasets. All authors had full access to the data. DM performed the statistical analysis and SH provided input on the statistical analysis. All authors contributed to the interpretation of the findings. PK, TB, and DM wrote the draft manuscript. All authors critically revised and provided feedback on the draft manuscript. All authors accept full responsibility for the content of the paper and have seen and approved the final manuscript. PK and TB contributed equally.

Data sharing statement

Deidentified individual participant data underlying the findings of this study will be available for researchers submitting a methodologically sound proposal to achieve the aims of the proposal. Proposals should be directed at the corresponding author (Prof. Dr. Milo A. Puhan, miloalan.puhan@uzh.ch).

Declaration of interests

JF reports receiving grants from Gilead Sciences Switzerland, ViiV healthcare, and Merck, unrelated to this work. The other authors declare no conflicts of interest.

Acknowledgements

This study is part of the Corona Immunitas research network, coordinated by the Swiss School of Public Health (SSPH+), and funded by fundraising of SSPH+ including funds of the Swiss Federal Office of Public Health and private funders (ethical guidelines for funding stated by SSPH+ were respected), by funds of the Cantons of Switzerland (Vaud, Zurich, and Basel) and by institutional funds of the Universities. Additional funding specific to this study was received from the Department of Health of the Canton of Zurich, the Swiss Federal Office of Public Health, the University of Zurich (UZH) Foundation, and the European Union's Horizon Europe Research and Innovation Programme under grant no 101046041 through the CoVICIS project. PK received funding from the Swiss National Science Foundation, grant no 100019M_201113. TB received funding from the European Union's Horizon 2020 Research and Innovation Programme under the Marie Skłodowska-Curie grant no 801076, through the SSPH + Global PhD Fellowship Program in Public Health Sciences (GlobalP3HS) of the SSPH+. JL received funding from Swiss Learning Health Systems (SHLS) through a PhD scholarship. DM received funding by the University of Zurich Postdoc Grant, grant no FK-22-053.

The authors thank the study administration team and the study participants for their continued and highly valuable support.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lanepe.2023.100671.

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