BMJ Open

Acute and long-term impacts of COVID-19 on economic vulnerability: a population-based longitudinal study (COVIDENCE UK)

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2022-065083
Article Type:	Original research
Date Submitted by the Author:	26-May-2022
Complete List of Authors:	Williamson, Anne; Barts and The London School of Medicine and Dentistry Blizard Institute Tydeman, Florence; Barts and The London School of Medicine and Dentistry Blizard Institute Miners, Alec; London School of Hygiene & Tropical Medicine, Department of Health Services Research and Policy Pyper, Kate; University of Strathclyde, Department of Mathematics and Statistics Martineau, Adrian; Barts and The London School of Medicine and Dentistry Blizard Institute
Keywords:	COVID-19, Economics < TROPICAL MEDICINE, Public health < INFECTIOUS DISEASES

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Acute and long-term impacts of COVID-19 on economic vulnerability: a population-based longitudinal study (COVIDENCE UK)

Anne E Williamson[1] (0000-0002-7421-9625)

Florence Tydeman[2]

Alec Miners[3]

Kate Pyper[4]

Adrian R Martineau[5†] (0000-0001-5387-1721)

1, Health Economist, Blizard Institute, Barts and The London School of Medicine and Dentistry, Queen Mary University of London, 4 Newark Street, London E1 2AT

2, Statistician, Blizard Institute, Barts and The London School of Medicine and Dentistry, Queen Mary University of London, 4 Newark Street, London E1 2AT

3, Associate Professor of Health Economics, Department of Health Services Research and Policy, London School of Hygiene and Tropical Medicine, London, UK

4, Statistician, Department of Mathematics and Statistics, University of Strathclyde

5, Professor of Respiratory Infection and Immunity, Institute of Population Health Sciences, Barts and The London School of Medicine and Dentistry, Queen Mary University of London, 4 Newark Street, London E1 2AT

Correspondence to Adrian R Martineau a.martineau@qmul.ac.uk

Abstract

Objective: To determine whether COVID-19 has a significant impact on the adequacy of household income to meet basic needs (primary outcome) and work absence due to sickness (secondary outcome), both at the onset of illness (acutely) and subsequently (long-term).

Design: Multivariate mixed regression analysis of self-reported data from monthly on-line questionnaires, completed 1st May 2020 to 28th October 2021, adjusting for baseline characteristics including age, sex, socioeconomic status and self-rated health.

Setting and Participants: Participants (n=16,910) were UK residents aged 16 years or over participating in a national longitudinal study of COVID-19 (COVIDENCE UK).

Results: Incident COVID-19 was independently associated with increased odds of participants reporting household income as being inadequate to meet their basic needs acutely (adjusted odds ratio [aOR) 1.39, 95% confidence interval [CI] 1.12 to 1.73) though this did not persist in the long-term (aOR 1.00, 95% CI 0.86 to 1.16). Exploratory analysis revealed a stronger acute association amongst those who reported 'long COVID', defined as the presence of symptoms lasting more than 4 weeks after the acute episode, than those reporting COVID-19 without 'long COVID' (p for trend 0.002). Incident COVID-19 associated with increased odds of reporting sickness absence from work in the long-term (aOR 4.73, 95% CI 2.47 to 9.06) but not acutely (aOR 1.34, 95% CI 0.52 to 3.49).

Conclusions: We demonstrate an independent association between COVID-19 and increased risk of economic vulnerability amongst COVIDENCE participants, measured by both household income sufficiency and sickness absence from work. Taking these findings together with pre-existing research showing that socio-economic disadvantage increases the risk of developing COVID-19, this may suggest a 'vicious cycle' of impaired health and poor economic outcomes.

Trial registration: NCT04330599

Summary Box

What is already known on this topic

- Socioeconomic deprivation is recognised as a major risk factor for incidence and severity of COVID-19 disease, mediated via factors including increased occupational and household exposure to SARS-CoV-2 and greater physical vulnerability due to comorbidities
- The potential for COVID-19 to act as a cause, rather than a consequence, of economic vulnerability has not previously been characterised.

What this study adds

- We demonstrate an independent association between incident COVID-19 and subsequent self-report of household income being inadequate to meet basic needs in the acute aftermath of infection.
- Incident COVID-19 was also associated with increased odds of subsequent self-report of sickness absence from work in the long-term.

Strengths and Limitations of this study

Strengths

- Prospective longitudinal study facilitated identification of temporal relationships between exposures and outcomes.
- Detailed demographic data allowing adjustment for multiple potential confounding factors in multivariable analyses.
- Rich dataset with two indicators of economic vulnerability to corroborate findings.

Limitations

- Rely on self-reported variables including COVID-19 test results and sufficiency of income for household needs.
- Although we obtained a large sample (n=16,910), this was imperfectly representative of the overall UK population.

Introduction

The coronavirus disease 2019 (COVID-19) pandemic has caused global health devastation, with huge mortality and morbidity worldwide. Socioeconomic deprivation was recognised as a major risk factor for incidence and severity of disease prior to the development and roll-out of vaccination against severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), mediated via factors including increased occupational and household SARS-CoV-2 exposure and greater physical vulnerability due to comorbidities.[1,2,3] This association persists in the vaccination era, with lower socioeconomic status associated with increased incidence and severity of breakthrough COVID-19.[4] However, the potential for COVID-19 to act as a cause, rather than a consequence, of economic vulnerability has received less research attention, despite the fact that sustained symptoms following an acute episode ('long COVID') are common, with potential to impact negatively on people's daily activities and capacity to work.[5]

One of the challenges in characterising effects of COVID-19 on economic well-being relates to the fact that societal measures to control the spread of COVID-19 are detrimental to employment and economic participation, and may therefore have negative economic impacts even in those who do not experience disease themselves.[1,6] Pre-pandemic analyses showed a relationship between economic downturns and increased mortality from causes including mental illness, cancer, and postulated 'deaths of despair' arising from suicide, drug overdose, or alcoholism.[7,8,9] This relationship is not straightforward, as parallel evidence found a decline in cardiovascular and traffic accident mortality during recessions.[10] Nonetheless, it is likely that pandemic-related economic contractions affect both health and economic wellbeing. The Brookings Institute draws a direct link from economic vulnerability to the COVID-19 pandemic, with particular harms from COVID-19-related poverty observed among populations who were already poor.[11]

In order to dissect out impacts of disease from the consequences of the societal response to the pandemic, we conducted a longitudinal cohort study that was initiated at the start of the pandemic, to determine whether incident COVID-19 was associated with

key markers of economic vulnerability. Economic vulnerability is defined here firstly as inability to pay for household basic needs, and secondly as impaired ability to earn further income. Consequently, our primary outcome was self-report of whether household income was sufficient to meet basic needs; this outcome captures individuals who consider themselves below the poverty line due to an adverse event.[12] Our secondary outcome captured participants' ability to earn income working by asking whether individuals who developed COVID-19 were more likely to report absence from work due to sickness. Associations between incident COVID-19 and both outcomes were explored both acutely (i.e. at the time when a positive SARS-CoV-2 test result was reported) and subsequently (i.e. in the long term).

Methods

Study design, setting and participants

COVIDENCE UK is a prospective cohort study (n=16,910) of COVID-19 in the UK population.[13] Its aims are to determine risk factors for incident COVID-19 in the UK population; to characterise the natural history of COVID-19 in the UK population; to evaluate the impact of COVID-19 on the physical, mental, and economic well-being of the UK population; and to provide a resource from which to identify potential participants for future clinical trials of interventions to prevent or treat acute respiratory infections. Leicester South Research Ethics Committee (ref 20/EM/0117) granted full ethics approval, and this study was registered with ClinicalTrials.gov (NCT04330599).

Inclusion criteria were age ≥16 years and UK residence at the point of enrolment. Recruitment was via a national media campaign across print newspapers, radio, television, and online advertising in order to reach a broad sample of the UK population across ages, ethnicities, socioeconomic groups, and other correlates of economic vulnerability. Participants initially completed an online baseline questionnaire capturing COVID-19 status and a wide range of demographic, socioeconomic and clinical characteristics described below. Follow-up questionnaires at monthly intervals captured incidence of RT-PCR- or lateral flow test-confirmed SARS-CoV-2 infection, long-term symptoms of COVID-19 ('long COVID'), and indicators of economic status. The survey

comprised a combination of validated instruments and other questions developed to specifically capture data relating to COVID-19. These questions were piloted with members of the Patient and Public Involvement Group, across a range of ethnicities and other demographic variables. Specific questions from baseline and monthly questionnaires whose responses contributed data to the current analysis are displayed in Supplementary Table 1 and Supplementary Table 2. The study launched on 1st May 2020, and this paper reports analyses of data collected up to 28th October 2021. All participants who responded to the baseline questionnaire and provided data on SARS-CoV-2 test status and adequacy of household income to meet basic needs in at least one monthly follow-up questionnaire were eligible for inclusion in this analysis. Exclusion criteria for this analysis were self-report of a positive SARS-CoV-2 test, 'long COVID', or hospitalisation for COVID-19 prior to completion of the baseline questionnaire, and self-report of 'long COVID' in the absence of a positive RT-PCR or lateral flow test result for SARS-CoV-2.

Definition of variables

Our primary outcome variable was self-report of a participant's household income being insufficient to meet their basic needs. This was derived as a binary variable based on responses to the question: "Since you last checked in with us, has your household income been sufficient to cover the basic needs of your household, such as food and heating?". Any answer other than 'yes' (namely: 'no', 'sometimes', or 'mostly') was coded as indicating insufficient income, whilst answering 'yes' was coded as indicating sufficient income. We also considered a secondary outcome associated with economic vulnerability, namely the ability to participate in the workforce. This was represented by a binary variable derived from responses to the question: "Which of the following best describes your current occupational status?". Participants selecting 'not working due to sickness, disability or illness' from a drop-down menu were coded as being absent from work due to sickness.

The following covariates were selected prior to analysis based on their potential to act as confounders of the relationship between incident COVID-19 and study outcomes:[14] age (classified as 'working age' [16-65 years] or 'not working age' [>65 years]), sex

(male *vs* female, defined by sex assigned at birth), ethnicity (classified as white or minority ethnic origin), country of residence (England, Scotland, Wales, or Northern Ireland), Index of Multiple Deprivation (IMD) quartile of residential area,[15] baseline occupational status (employed, self-employed, retired, furloughed, unemployed, student, never employed, not working due to sickness/disability/illness, or 'other'), housing status (owns home outright, mortgage holder, private rental, renting from council, or other) and self-reported general health (poor, fair, good, very good, or excellent).

The principal independent variable of interest for our analysis main model was SARS-CoV-2 test positivity. This was defined by a binary indicator where 'yes' included any self-reported positive lateral flow or RT-PCR SARS-CoV-2 test result, and 'no' included either a self-reported negative lateral flow or RT-PCR SARS-CoV-2 test result or no report of any test taken. Associations between this variable and our two outcomes of interest were considered over two time periods. First, we built an 'acute' model to examine short-term effects of COVID-19 by asking whether SARS-CoV-2 test positivity was associated with increased risk of reporting insufficient income or sickness absence in the same month as the positive result was recorded. Second, we built a 'long-term' model to test whether the risk of reporting insufficient income or sickness absence was associated with a positive SARS-CoV-2 test result in subsequent months, excluding the month of infection.

We also conducted two exploratory analyses to determine whether there was a dose-response relationship for associations between COVID-19 severity and risk of reporting insufficient income. This was implemented by categorising participants reporting a positive SARS-CoV-2 test result according to their response to the question "Would YOU say that you currently have 'long COVID', i.e. ongoing symptoms more than four weeks after the onset of proven or suspected COVID-19?". We compared those reporting 'long COVID' and those reporting a positive SARS-CoV-2 test result but no 'long COVID' to those without a positive SARS-CoV-2 test result (the referent category). Second, we categorised participants reporting a positive SARS-CoV-2 test result according to whether or not they were hospitalised, comparing those reporting

hospitalisation for COVID-19 and those reporting COVID-19 not requiring hospitalisation to those without a positive SARS-CoV-2 test result (the referent category). Both of these exploratory analyses were conducted for the acute and long-term models as described above.

Statistical analysis

Mixed effects logistic regression models were applied to assess the relationship between positive SARS-CoV-2 test results (RT-PCR or lateral flow) and reported insufficient income at any point prior to 28th October 2021 in the main analysis. A random effect of unique participant identifier was included in all models to account for repeated measures, allowing assessment of within-participant variability. These analyses were adjusted for baseline socio-demographic characteristics as outlined above.

For analyses exploring potential impacts of 'long COVID' and disease precipitating hospitalisation, a random effect for a unique participant identifier was also included to account for repeated measures, with adjustment for baseline characteristics as before, and substitution of the monthly-varying binary principal independent variable indicating SARS-CoV-2 test status with one of the other 3-level key independent variables as previously defined above (i.e. positive SARS-CoV-2 test result with subsequent 'long COVID', positive SARS-CoV-2 test result without 'long COVID' *vs* no positive SARS-CoV-2 test result, OR positive SARS-CoV-2 test result with hospitalisation, positive SARS-CoV-2 test result without hospitalisation *vs* no positive SARS-CoV-2 test result). The models including these 3-level variables were evaluated twice, firstly as standard categorical variables and then secondly exchanging categorical versions for numerical integers, which provided a p-value for trend for 'long COVID' and hospitalisation due to COVID-19 respectively, for both acute and long-term models. Models for each of these monthly-varying exploratory analyses were built separately from one another, and from the main model which categorised incident COVID-19 as a binary independent variable.

Mixed effects logistic regression models were also applied to assess the relationship between a positive SARS-CoV-2 test result and reported absence from work due to sickness at any point prior to 28th October 2021. The insufficient income variable was

not included in this secondary outcome model, and 'long COVID' and hospitalisation were also not considered. Missing data were assumed to be missing completely at random (MCAR) and were handled with listwise deletion in the generalised linear mixed models so that unbiased estimates were obtained. All statistical analyses were conducted using R version 4.1.1 with the mixed effects models conducted using R-package `lmer4`.

Sub-group analyses

We tested for effect modification by including interaction terms for SARS-CoV-2 test positivity and age (categorised as ≤65 or >65 years) and sex (categorised as male or female at birth) in multivariable models investigating determinants of our primary outcome.

Patient and public involvement

Three patient and public involvement representatives were involved in development of the research questions and the choice of outcome measures specified in the study protocol. One of them also led on development and implementation of strategies to maximise participant recruitment. Results of work will be disseminated to individual participants via a webinar.

Results

19,980 participants completed the COVIDENCE UK baseline questionnaire between 1st May 2020 and 29th October 2021, of whom 1,412 did not complete any subsequent monthly questionnaire. Of the remaining 18,568 participants, 16,910 (91.2%) contributed data to the current analysis. Reasons for exclusion of the 1,658 participants who did not contribute data to this analysis are detailed in the participant flow diagram (Supplementary Appendix Figure S1). Table 1 presents baseline characteristics of participants contributing data to this analysis: their median age was 63 years, 69.8% were female, 94.7% were of White ethnic origin, 2.7% were receiving universal credit payments, 6.9% reported their household income as being 'sometimes', 'mostly' or 'not' sufficient to meet their basic needs in the month prior to enrolment, and 1.7% reported

not working due to sickness. Figure 1 illustrates response flows in sufficiency of income to meet basic household needs over time.

Table 1: Participant characteristics at baseline

		Number Participants (%)
Sex	Male	5106 (30.2%)
	Female	11,804 (69.8%)
Working age	Yes (16-65)	10,338 (61.1%)
	No	6570 (38.9%)
Ethnicity	Minority ethnic	894 (5.3%)
	White	16,015 (94.7%)
Country	Scotland	1029 (6.1%)
	Wales	604 (3.6%)
	Northern Ireland	314 (1.9%)
	England	14,956 (88.4%)
IMD Quartile	1 (most deprived)	3990 (23.6%)
	2	4191 (24.8%)
	3	4299 (25.4%)
	4 (least deprived)	4410 (26.1%)
Claiming universal credit	Yes	464 (2.7%)
	No	16,390 (96.9%)
Occupation	Self-employed	1554 (9.2%)
	Retired	7547 (44.6%)
	Furloughed	386 (2.3%)
	Unemployed	296 (1.8%)
	Student	345 (2.0%)
	Other	394 (2.3%)
	Never Employed	10 (0.01%)
	Not working due to sickness	281 (1.7%)
	Employed	6097 (36.1%)
Housing	Mortgage	4250 (25.1%)
	Private Renting	1227 (7.3%)
	Renting Council	531 (3.1%)
	Other	724 (4.3%)
	Owns home	10,174 (60.2%)
Self-reported general health	Poor	480 (2.8%)
	Fair	1808 (10.7%)
	Good	4537 (26.8%)
	Very good	6691 (39.6%)
	Excellent	3394 (20.1%)
Income sufficient to cover basic needs	Yes	15,749 (93.1%)
	Mostly	617 (3.6%)
	Sometimes	147 (0.9%)
	No	396 (2.3%)

1 Missing data: working age (N = 2, 0.01%), ethnicity (N = 1, <0.01%), country (N = 7, 0.04%), IMD quartile (N = 20, 0.12%), housing (N = 4, 0.02%), universal credit (N = 56, 0.3%), income sufficient (N = 1,<0.01%).

A total of 1,120 participants reported a positive SARS-CoV-2 test result at least once between enrolment and the end of follow-up (28th October 2021). Of these, 39/1120 (3.5%) were hospitalised for COVID-19, and 308/1120 (27.5%) reported 'long COVID'. A total of 7310/16,910 (43.3%) participants reported insufficient income on one or more occasions and 398/16,910 (2.4%) reported absence from work due to sickness on one or more occasions during follow-up (Supplementary Table 3).

Incident COVID-19 was independently associated with increased odds of participants reporting household income as being inadequate to meet their basic needs in multivariable analyses, both acutely (aOR 1.39, 95% CI 1.12 to 1.73) though this did not persist in the long-term (aOR 1.00, 95% CI 0.86 to 1.16) (Table 2). Of the eight covariates included in each model, independent associations with increased risk of reporting insufficient income were also seen for non-White vs White ethnicity, younger vs older age (≤65 vs >65 years), higher vs lower deprivation quartile, poorer vs better health at baseline, being self-employed, furloughed, other (including sick) or unemployed vs being employed at baseline, and having a mortgage, privately renting, or renting from the council vs owning their home outright. Neither sex nor age modified the association between SARS-CoV-2 test-positivity and reporting insufficient income (for sex, P for interaction = 0.23 and 0.51 for acute and long-term models, respectively; for age, P for interaction =0.48 and 0.14 for acute and long-term models, respectively).

Table 2: Determinants of reporting insufficient income during follow-up

		Acute Responses		Long-term Responses	
Variable	Response	Adjusted OR (95% CI)	P	Adjusted OR (95% CI)	P
Incident COVID-19	Yes	1.39 (1.12 to 1.73)	0.002	1.00 (0.86 to 1.16)	0.977
	No	1.00	-	1.00	--
Sex	Male	1.03 (0.90 to 1.11)	0.548	1.03 (0.93 to 1.15)	0.564
	Female	1.00	-	1.00	-
Age, years	16-65	1.63 (1.41 to 1.87)	<0.001	1.59 (1.39 to 1.83)	<0.001
	>65	1.00	-	1.00	-
Ethnicity	Minority ethnic	1.83 (1.49 to 2.27)	<0.001	1.85 (1.49 to 2.27)	<0.001
	White	1.00	-	1.00	-
Country	Scotland	1.01 (0.80 to 1.28)	0.916	1.01 (0.80 to 1.28)	0.942
	Wales	0.82 (0.61 to 1.09)	0.164	0.82 (0.61 to 1.10)	0.187
	Northern Ireland	0.91 (0.62 to 1.31)	0.588	0.91 (0.63 to 1.32)	0.611
	England (ref)	1.00	-	1.00	-
IMD Quartile	1 (most deprived)	1.51 (1.27 to 1.79)	<0.001	1.37 (1.17 to 1.60)	<0.001
	2	1.26 (1.10 to 1.44)	<0.001	1.20 (1.06 to 1.4536)	0.005
	3	1.04 (0.91 to 1.20)	0.535	1.04 (0.91 to 1.18)	0.571
	4 (least deprived, ref)	1.00	-	1.00	-
Occupation	Self-employed	1.73 (1.45 to 2.06)	<0.001	1.84 (1.54 to 2.19)	<0.001
	Retired	0.63 (0.55 to 0.72)	0.031	0.82 (0.71 to 0.96)	0.013
	Furloughed	2.18 (1.60 to 2.97)	<0.001	2.17 (1.59 to 2.96)	<0.001
	Unemployed	7.76 (5.50 to 11.0)	<0.001	7.66 (5.43 to 10.83)	<0.001
	Student	1.15 (0.81 to 1.64)	0.558	1.12 (0.78 to 1.59)	0.549
	Other/never employed/sick	2.08 (1.59 to 2.62)	<0.001	2.07 (1.61 to 2.66)	<0.001
	Employed (ref)	1.00	-	1.00	-
Housing	Mortgage	1.66 (1.45 to 1.89)	<0.001	1.53 (1.34 to 1.74)	<0.001
	Private Renting	4.55 (3.75 to 5.53)	<0.001	4.35 (3.58 to 5.28)	<0.001
	Renting Council	11.6 (8.81 to 15.30)	<0.001	11.5 (8.72 to 15.10)	<0.001
	Other	2.94 (2.28 to 3.79)	<0.001	2.77 (2.15 to 3.57)	<0.001
	Owns home (ref)	1.00	-	1.00	-
Self-reported general health	Poor	5.32 (3.94 to 7.18)	<0.001	5.38 (3.98 to 7.26)	<0.001
	Fair	3.41 (2.84 to 4.09)	<0.001	3.47 (2.88 to 4.14)	<0.001
	Good	1.98 (1.72 to 2.29)	<0.001	2.01 (1.74 to 2.33)	<0.001
	Very good	1.21 (1.06 to 1.39)	0.003	1.23 (1.07 to 1.40)	0.003
	Excellent (ref)	1.00	-	1.00	-

To explore these findings further, we investigated whether associations between incident COVID-19 and income insufficiency were stronger for the subset of participants who either reported 'long COVID' or who were hospitalised for COVID-19 treatment. Results are shown in Table 3: point estimates for adjusted ORs in the acute model were higher for those who reported 'long COVID' or hospitalisation than for those who did not (P values for trend 0.002 for both 'long COVID' and hospitalisation). We also note clinical interest in the direction of association shown in the long-term 'long COVID' model (aOR 1.26, 95% CI 0.98 to 1.61) with a confidence interval crossing 1 but leaning in positive direction.

Table 3: Impact of self-reported 'long COVID' and hospitalisation for COVID-19 on reporting insufficient income during follow-up

		Acute Responses		Long-term Responses	
Variable	Response	Adjusted OR (95% CI)	P	Adjusted OR (95% CI)	P
Self-report 'long COVID'	No COVID-19 (ref)	1.00	-	1.00	-
	COVID-19, no 'long COVID'	1.44 (1.15 to 1.80)	0.003	0.90 (0.75 to 1.08)	0.263
	'Long COVID'	1.50 (1.14 to 1.95)	0.002	1.26 (0.98 to 1.61)	0.067
	P for trend	-	0.002	-	0.477
Hospitalisation due to COVID-19	No COVID-19 (ref)	1.00	-	1.00	-
	COVID-19, not hospitalised	1.37 (1.10 to 1.71)	0.002	0.99 (0.85 to 1.16)	0.942
	COVID-19, hospitalised	1.91 (0.694 to 5.25)	0.220	1.38 (0.69 to 2.78)	0.365
	P for trend	-	0.002	-	0.902

2 Multivariable regression models fully adjusted for the following baseline variables: sex, age, ethnicity, country, IMD quartile, occupation, housing and self-reported general health.

Finally, we examined whether incident COVID-19 was associated with our secondary outcome of absence from work due to sickness. Results are presented in Table 4: incident COVID-19 was associated with increased odds of reporting sickness absence from work in the long-term (aOR 4.73, 95% CI 2.47 to 9.06) but not acutely (aOR 1.34, 95% CI 0.52 to 3.49).

Table 4: Determinants of reporting 'not working due to sickness' during follow-up

		Acute Response		Long-term Response	
Variable	Response	Adjusted OR (95% CI)	P	Adjusted OR (95% CI)	P
Incident COVID-19	Yes	1.34 (0.52 to 3.49)	0.54	4.73 (2.47 to 9.06)	<0.001
	No	1.00	-	1.00	
Sex	Male	0.58 (0.52 to 2.24)	0.433	0.58 (0.15 to 2.24)	0.427
	Female (ref)	1.00	-	1.00	-
Working age	Yes (16-65)	14.5 (1.57 to 134.0)	0.018	13.82 (1.48 to 129.30)	0.021
	No (ref)	1.00	-	1.00	-
Ethnicity	Minority ethnic	0.76 (0.08 to 6.75)	0.814	0.75 (0.15 to 11.53)	0.805
	White (ref)	1.00	-	1.00	-
Country	Scotland	0.44 (0.04 to 5.03)	0.508	0.47 (0.04 to 5.51)	0.550
	Wales	0.98 (0.07 to 14.80)	0.992	0.95 (0.06 to 14.64)	0.972
	Northern Ireland	0.59 (0.03 to 12.11)	0.731	0.57 (0.03 to 12.25)	0.717
	England (ref)	1.00	-	1.00	-
IMD Quartile	1 (most deprived)	1.59 (0.31 to 8.24)	0.587	1.57 (0.30 to 8.28)	0.594
	2	1.06 (0.21 to 5.29)	0.948	1.08 (0.21 to 5.46)	0.923
	3	1.03 (0.19 to 5.49)	0.970	1.02 (0.19 to 5.47)	0.986
	4 (least deprived, ref)	1.00	-	1.00	-
Housing	Mortgage	0.76 (0.19 to 3.07)	0.702	0.74 (0.18 to 3.00)	0.671
	Private Renting	1.60 (0.30 to 8.64)	0.587	1.58 (0.29 to 8.58)	0.595
	Renting Council	8.62 (1.96 to 37.8)	0.004	8.56 (1.92 to 38.19)	0.005
	Other	1.56 (0.22 to 11.1)	0.042	1.53 (0.21 to 10.98)	0.673
	Owns home (ref)	1.00	-	1.00	-
Self-reported general health	Poor	94.6 (5.82 to 1540.0)	0.001	101.80 (6.13 to 1689.72)	0.001
	Fair	17.6 (1.12 to 276.0)	0.042	17.93 (1.12 to 287.80)	0.042
	Good	3.86 (0.23 to 66.0)	0.352	3.94 (0.23 to 68.90)	0.348
	Very good	2.24 (0.12 to 40.8)	0.587	2.28 (0.12 to 42.57)	0.580
	Excellent (ref)	1.00	-		-

Discussion

To our knowledge, this study is the first to investigate the impact of COVID-19 on subsequent risk of becoming economically vulnerable. We report that incident COVID-19 was independently associated with increased risk of participants reporting insufficient household income acutely, though not in the long-term. The acute association was stronger where COVID-19 precipitated 'long COVID' or hospitalisation, supporting causal interpretation. Incident COVID-19 was also associated with increased risk of participants reporting absence from work due to sickness in the long-term.

Our findings accord with those of studies that have investigated the impact of other infectious diseases on economic outcomes. People living with HIV have been reported to experience higher rates of severe poverty, employment loss and impaired physical and mental functioning.[16,17,18] Similar analyses revealed a link between tuberculosis and increased poverty in both the UK and India.[19,20] However, these studies were all cross-sectional in design, leaving uncertainty as to whether the diseases in question were a cause or consequence of the observed poverty.

Our analysis aimed to identify whether there is evidence of an association between these outcomes in a specific direction of causality, i.e. from disease to economic vulnerability. The prospective design employed in the current study was valuable to this end, as it allowed us to focus on the timing of onset of the relationship between incident COVID-19 and subsequent economic vulnerability. Demonstration of a dose-response relationship between severity of COVID-19 and the primary outcome, along with consistency of association for two different measures of economic vulnerability (inadequate income and sickness absence) both strengthen the case for causal interpretation.[22]

Taking these findings together with other research showing that socio-economic disadvantage increases the risk of developing COVID-19,[1,2,3,4] our current study represents an important advance by indicating that the relationship between COVID-19 and socio-economic deprivation may be bi-directional. This suggests a 'vicious cycle' of poor health and economic vulnerability which individuals could be pushed into, or accelerated along, by COVID-19. The poorer someone was, is the more likely they were

to fall sick. If they did fall sick, they were more likely to experience poverty during the pandemic, with further health risks.

It is notable that incident COVID-19 had a significant negative impact on self-assessed adequacy of household income acutely, whereas the impact on work absence due to sickness was only evident in the long-term. One potential reason for this is that those acutely ill with COVID-19 would still self-classify as 'employed' but on temporary leave, whilst persistent COVID-19 symptoms might lead to a change in status to official sickness absence. This raises the possibility that COVID-19 may impact economic vulnerability through multiple mechanisms including non-employment-based mechanisms in the short term, such as increased health-related costs, and employment-based mechanisms in the longer term. Early, decisive policy interventions could help prevent this potential vicious cycle, with employment advice and other economic support offered alongside healthcare follow-up at hospital discharge.

Our study has several strengths. Its large size afforded ample power to detect potential impacts of COVID-19 on our primary and secondary outcomes, while its population-based recruitment and prospective design maximises generalisability of our findings while allowing us to characterise temporal relationships between exposures and outcomes. Detailed characterisation of participants allowed us to adjust for multiple potential confounding factors in multivariable analyses, and to explore two different indicators of economic vulnerability.

This work also has limitations. First, the variables of interest are all self-reported, including both SARS-CoV-2 test results and indicators of economic vulnerability. Participants were unaware of the hypotheses tested in this work, however, reducing potential for reporter bias to operate. We also relied on reports of voluntary tests, which allows the possibility that some COVID-positive individuals did not receive a test and thus were treated as negative. However, testing was readily available and mandatory for many workplaces and all individuals with symptoms throughout the study period. Participant exclusion criteria also included "self-report of 'long COVID' in the absence of a positive RT-PCR or lateral flow test result for SARS-CoV-2". This minimises the

likelihood of a symptomatic individual classified as test-negative. Nonetheless, some with asymptomatic infection may still have been misclassified.

Second, the study population was not perfectly representative of the adult UK population as a whole: males, younger people, people of minority ethnic origin and those with lower educational attainment were all under-represented. Caution is therefore required when extrapolating conclusions beyond the sample population. Further, internet access was a prerequisite to take part, which could limit generalisability of results particularly amongst the most economically deprived. While this may have limited our power to detect associations within sub-groups, we highlight that representativeness is not necessarily a barrier to identification of causal associations in observational epidemiology.[21]

Fourth, we acknowledge that the precise order of COVID-19 and economic events cannot be guaranteed by our acute model. We cannot rule out the theoretical possibility that a negative economic shock in the same month preceded COVID infection for some individuals. Nonetheless, this is unlikely to drive the majority of the effect identified, as we do not see a plausible mechanism for an economic shock to precipitate COVID-19 infection in a matter of days. The reverse relationship, where infection precedes economic vulnerability, remains more plausible. We also note that the findings of this acute model are consistent with both the 'long COVID' and long-term sickness absence models, which increases confidence that COVID-19 infection preceded economic vulnerability for the vast majority of participants considered.

Finally, as with any observational study, residual or unmeasured confounding cannot be ruled out as an explanation for the associations we observe. We handled missing data under the assumption that survey data were missing at random, but it is possible that data were more likely to be missing if someone had COVID-19 or became economically vulnerable. In the most extreme case, fatal or very severe COVID-19 would prevent questionnaire completion; alternatively, someone may have become ill or lost their job then no longer have the cognitive or physical capacity to complete the questionnaires. Conversely, it is possible that SARS-CoV-2 test positivity may have increased the likelihood of participants completing their monthly follow-up questionnaires.

Our findings highlight the need for further research in three areas. First, analogous studies should be done in other populations to determine whether our findings can be replicated; ideally such studies should capture details of longitudinal earnings to introduce greater objectivity and quantification of impacts while reducing reporting bias. Second, further work is needed to understand the specific mechanisms by which COVID-19 may lead to economic vulnerability, investigating the relative importance of factors including lost employment, 'long COVID' symptoms and stigmatisation. Third, our findings suggest the need for further work to explore bi-directional relationships between illness and deprivation more generally.

In conclusion, we report independent associations between incident COVID-19 and subsequent development of economic vulnerability, exposing a previously hidden human cost of the pandemic. Our findings have potentially significant policy implications, given the economic imperative to plan COVID-19-related spending in the most efficient way possible. While a 'vicious cycle' of sickness and poverty presents a major threat to wellbeing, its recognition could also offer an opportunity for effective, early-stage circuit-breaker interventions with potential to avert greater costs in the future.

Ethics Approval Statement

COVIDENCE UK was sponsored by Queen Mary University of London and approved by Leicester South Research Ethics Committee (ref 20/EM/0117). It is registered with ClinicalTrials.gov (NCT04330599).

Contributorship Statement

The corresponding author attests that all listed authors meet all four ICMJE authorship criteria and that no others meeting the criteria have been omitted. The corresponding author affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as originally planned (and, if relevant, registered) have been explained.

Competing Interests and Funding

All authors have completed the ICMJE uniform disclosure form at http://www.icmje.org/disclosure-of-interest/ and declare: this study was supported by a grant from Barts Charity to ARM (MGU0466). The funder had no role in any aspect of the study design; in the collection, analysis, and interpretation of data; in the writing of the report; or in the decision to submit the article for publication. We confirm the independence of researchers from funders and that all authors, external and internal, had full access to all of the data (including statistical reports and tables) in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis.

Data Sharing Statement

De-identified participant data will be made available upon reasonable request to Prof Martineau (a.martineau@qmul.ac.uk), subject to terms of Research Ethics Committee approval and Sponsor requirements.

References

1. Blundell R, Costa Dias M, Joyce R, Xu X. COVID-19 and Inequalities. *Fiscal Studies*. 2020; 41(2); 291-319.
2. Holt H, Talaei M, Greenig M*, et al.* Risk factors for developing COVID-19: a population-based longitudinal study (COVIDENCE UK). *Thorax* Epub ahead of print: 30 November 2021. doi: 10.1136/thoraxjnl-2021-217487
3. Ahmed F, Ahmed N, Pissarides C, Stiglitz J. Why inequality could spread COVID-19. *The Lancet Public Health.* 2020; 5(5); e240.
4. Antonelli M, Penfold RS, Merino J, et al. Risk factors and disease profile of post-vaccination SARS-CoV-2 infection in UK users of the COVID Symptom Study app: a prospective, community-based, nested, case-control study. *The Lancet Infectious Diseases*. 2022; 22(1); 43-55.
5. NHS Employers. *Supporting recovery after long COVID.* 2021. Available from: https://www.nhsemployers.org/articles/supporting-recovery-after-long-covid
6. De Vos J. The effect of COVID-19 and subsequent social distancing on travel behaviour. *Transportation Research Interdisciplinary Perspectives.* 2020; 5.
7. Burgard, S.A. and Kalousova, L., 2015. Effects of the Great Recession: Health and well-being. Annual Review of Sociology, 41, pp.181-201.
8. Deaton A, Case A. *Deaths of Despair and the Future of Capitalism.* Princeton: Princeton University Press; 2020.
9. Friebel, R., Yoo, K.J. and Maynou, L., 2022. Opioid abuse and austerity: evidence on health service use and mortality in England. Social Science & Medicine, 298, p.114511.
10. Strumpf, E.C., Charters, T.J., Harper, S. and Nandi, A., 2017. Did the Great Recession affect mortality rates in the metropolitan United States? Effects on mortality by age, gender and cause of death. Social Science & Medicine, 189, pp.11-16.
11. Graham C. The human costs of the pandemic: Is it time to prioritize well-being? *Brookings Institute*. 2020. Available from: https://www.brookings.edu/research/the-human-costs-of-the-pandemic-is-it-time-to-prioritize-well-being/ [Accessed 14th December 2021].
12. Chaudhuri, S. Assessing vulnerability to poverty: Concepts, empirical methods and illustrative examples. *Department of Economics, Columbia University, New York.* 2003. Available from: http://econdse.org/wp-content/uploads/2012/02/vulnerability-assessment.pdf
13. Talaei M, Faustini S, Holt H, *et al.* Determinants of pre-vaccination antibody responses to SARS-CoV-2: a population-based longitudinal study (COVIDENCE UK). *BMC Med* **20,** 87 (2022). doi: 10.1186/s12916-022-02286-4.
14. Van der Weele T. Principles of confounder selection. *Eur J Epidemiol.* 2019; 34(3); 211-219.
15. Ministry of Housing, Communities and Local Government. The English Indices of Deprivation 2019. 2019.

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/853811/IoD2019_FAQ_v4.pdf

16. National AIDS Trust. Extreme poverty among people with HIV in the UK increasing. 2010. Available from: https://www.nat.org.uk/press-release/extreme-poverty-among-people-hiv-uk-increasing
17. Dray-Spira R, Gueguen A, Lert F, VESPA Study Group. Disease severity, self-reported experience of workplace discrimination and employment loss during the course of chronic HIV disease: differences according to gender and education. *Occupational and environmental medicine*. 2008; 65(2); 112–119.
18. APA. HIV/AIDS and Socioeconomic Status. *American Psychological Association.* 2010. Available from: https://www.apa.org/pi/ses/resources/publications/hiv-aids
19. Spence D, Hotchkiss J, Williams C, Davies P. Tuberculosis and poverty. *British Medical Journal.* 1993; 307; 759-761.
20. Rajeswari R, Balasubramanian R, Muniyandi M, Geetharamani S, Thresa X, Venkatesan P. Socio-economic impact of tuberculosis on patients and family in India. *Int J Tuberc Lung Dis.* 1999; 3(10); 869-77.
21. Rothman KJ, Gallacher JEJ, Hatch EE. Why representativeness should be avoided. *International Journal of Epidemiology*. 2013; 42(4); 1012–1014.
22. Hill A. The Environment and Disease: Association or Causation?. *Proceedings of the Royal Society of Medicine*. 1965; 58 (5): 295–300.

Figure 1: Sankey diagram illustrating response flows in sufficiency of income to meet basic household needs over time.

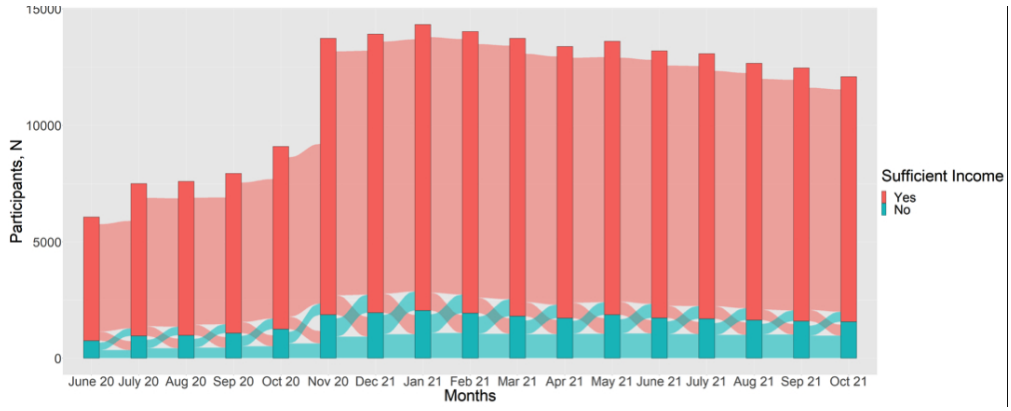


Figure 1: Sankey diagram illustrating response flows in sufficiency of income to meet basic household needs over time.

462x185mm (59 x 59 DPI)

Short- and long-term impacts of COVID-19 on economic vulnerability: a population-based longitudinal study (COVIDENCE UK)

Supplementary Material

Table S1: Baseline questionnaire

Sociodemographic	
Date of birth (DD/MM/YYYY)	
Date of questionnaire (DD/MM/YYYY)	
Post code	
Please state your **assigned sex at birth.**	-Male -Female
What is your ethnic origin?	- White - English / Welsh / Scottish / Northern Irish / British - Irish - Gypsy or Irish Traveller - Any other white background - Mixed / Multiple ethnic groups - White and Black Caribbean - White and Black African - White and Asian - Any other Mixed / Multiple ethnic backgrounds - Asian / Asian British - Indian - Pakistani - Bangladeshi - Chinese - Any other Asian background - Black / African / Caribbean / Black British - African - Caribbean - Any other Black / African / Caribbean background - Arab - Other Ethnic Group
In the last month, was your household income sufficient to cover the basic needs of your household, such as food and heating?	- Yes - Mostly - Sometimes - No
Please select the box that best describes your current housing situation:	- I own my home outright - I own my home and I am paying a mortgage - I am renting privately - I am renting from the council/housing association - I am staying with friends or family - I am homeless or living in temporary accommodation - Other
Do you currently claim Universal Credit?	- Yes, I have applied to receive Universal Credit but have **not yet** received any payments - Yes, I have claimed Universal Credit and received **one or more** payments - No
Which of the following best describes your current occupational status?	- Employed - Self-employed - Retired - Furloughed - Unemployed - Student - Never employed - Not working due to sickness/disability or illness - Other
Over the last 12 months, would you say that on the whole, your health has been:	- Excellent - Very good - Good - Fair - Poor
Since February 1st 2020, have you had a nose/throat swab to test for COVID-19?	- Yes - No
On what date did you have this nose/throat swab? If you are not sure of the exact date, enter the approximate date (DD/MM/YYYY).	

e.g. 25/04/2020	
What was the result?	- Positive - Negative - Not known

Table S2: Monthly follow-up questionnaire

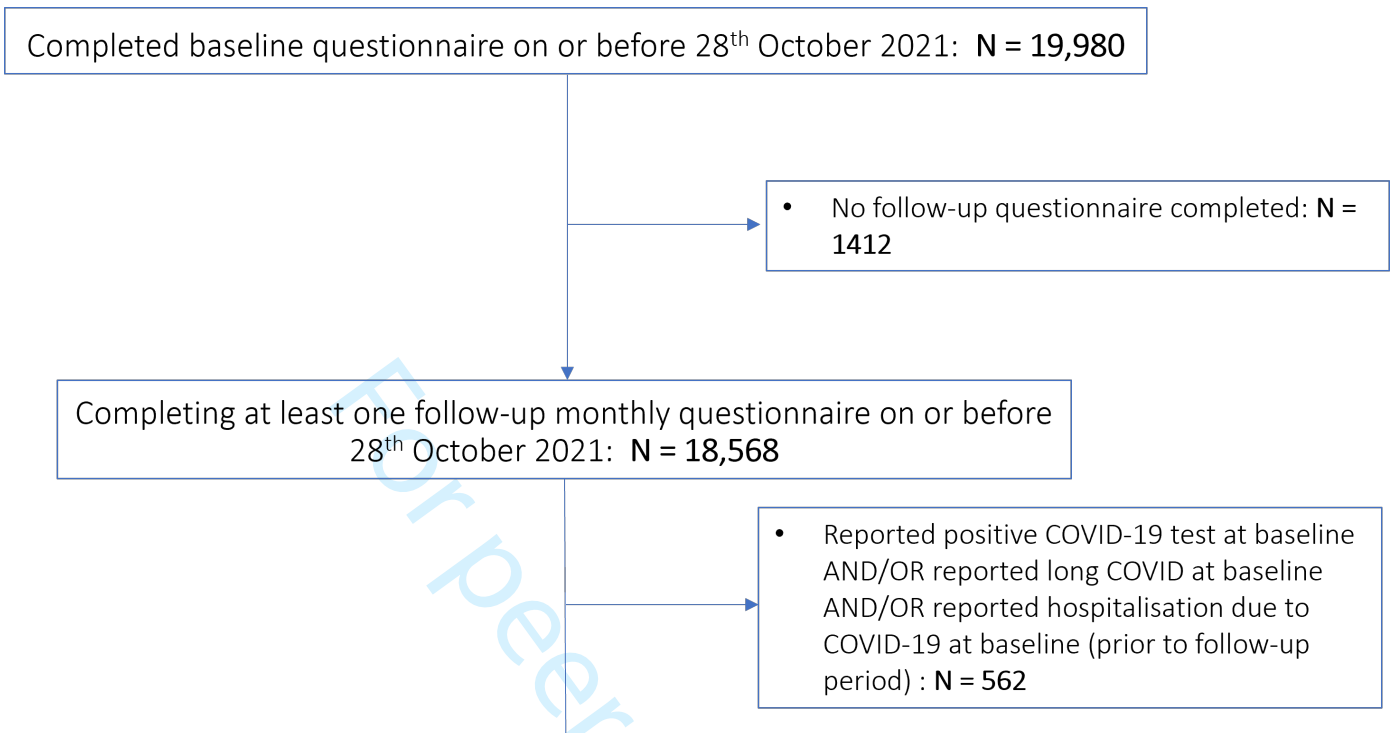
Questions asked at every monthly follow-up	
Since you last checked in with us, have you had a nose or throat swab for COVID-19 or any other respiratory virus, or has a result from a previous swab test become newly available?(This question is about tests to detect the virus itself: they are usually done in somebody who has symptoms, but screening of asymptomatic people can also be done. It's usually a nose/throat swab, but saliva tests are also becoming available)	- Yes - No
On what date did you have this nose / throat swab? If you are not sure of the exact date, enter the approximate date (DD/MM/YYYY).	
What was the result? Click as many as apply.	- Positive for COVID-19 (SARS-CoV-2 coronavirus) - Positive for influenza virus - Positive for another respiratory virus - Negative for all/any viruses tested - Not Known
Did you go to hospital for treatment of these symptoms?	- Yes, and I was admitted to hospital (i.e. I spent one or more nights as a hospital in-patient) - Yes, I attended a hospital accident and emergency department but I was not admitted to hospital (i.e. I went home without spending one or more nights as a hospital in-patient) - No, I didn't go to hospital for treatment of these symptoms
What did the hospital doctors diagnose?	- Suspected or proven COVID-19 - Something else
Would YOU say that you currently have 'long COVID', i.e. ongoing symptoms more than four weeks after the onset of proven or suspected COVID-19?	- Yes - No - Don't know/not sure
Since you last checked in with us, has your household income been sufficient to cover the basic needs of your household, such as food and heating?	- Yes - Mostly - Sometimes - No
Has your employment status changed since you last checked in with us?	- Yes - No
Which of the following best describes your current occupational status?	- Employed - Self-employed - Retired - Furloughed - Unemployed - Student - Never employed - Not working due to sickness/disability or illness - Other

Table 3: Summary of participant response numbers for monthly-varying independent and dependent variables

	Reponses	Number Participants (%)
Dependent Variables		
Income sufficient	No	7310 (43.3%)
	Yes	9600 (64.7%)
Not working due to sickness	Yes	398 (2.4%)
	No	16,512 (97.6%)
Independent Variables		
Incident COVID-19	Yes	1120 (6.6%)
	No	15,790 (93.4%)
Self-reported 'long COVID'	'Long COVID'	308 (1.8%)
	COVID-19, never 'long COVID'	812 (4.8%)
	No COVID-19	15,790 (93.4%)
Hospitalisation due to COVID-19	COVID-19, hospitalised	39 (0.2%)
	COVID-19, never hospitalised	1089 (6.5%)
	No COVID-19 (ref)	15,782 (93.3%)

1Participant numbers are reported here based on whether they EVER report the answer of interest during follow-up. For income sufficiency, they are coded as 'no' if they answer 'no', 'sometimes' or 'mostly' at least once during follow-up. For sickness absence, incident COVID-19, 'long COVID', and hospitalisation, they are coded as 'yes' if they 'yes' for the relevant variable at least once during follow-up.

Figure S1: Participant flow diagram



STROBE Statement

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	5
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	n/a
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6
Bias	9	Describe any efforts to address potential sources of bias	8
Study size	10	Explain how the study size was arrived at	9
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	8
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	8
		(*e*) Describe any sensitivity analyses	7-8

Continued on next page

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	9
		(c) Consider use of a flow diagram	Supp Fig 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	9, Supp Table 3
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	9
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	Supp Table 3
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	*n/a*
		Cross-sectional study—Report numbers of outcome events or summary measures	*n/a*
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6, 17-19
		(*b*) Report category boundaries when continuous variables were categorized	17, 19
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10
Discussion			
Key results	18	Summarise key results with reference to study objectives	10-11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11
Generalisability	21	Discuss the generalisability (external validity) of the study results	12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Short-term and long-term impacts of COVID-19 on economic vulnerability: a population-based longitudinal study (COVIDENCE UK)

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2022-065083.R1
Article Type:	Original research
Date Submitted by the Author:	01-Jul-2022
Complete List of Authors:	Williamson, Anne; Barts and The London School of Medicine and Dentistry Blizard Institute Tydeman, Florence; Barts and The London School of Medicine and Dentistry Blizard Institute Miners, Alec; London School of Hygiene & Tropical Medicine, Department of Health Services Research and Policy Pyper, Kate; University of Strathclyde, Department of Mathematics and Statistics Martineau, Adrian; Barts and The London School of Medicine and Dentistry Blizard Institute
Primary Subject Heading:	Respiratory medicine
Secondary Subject Heading:	Public health, Infectious diseases
Keywords:	COVID-19, Economics < TROPICAL MEDICINE, Public health < INFECTIOUS DISEASES

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Short-term and long-term impacts of COVID-19 on economic vulnerability: a population-based longitudinal study (COVIDENCE UK)

Anne E Williamson[1] (0000-0002-7421-9625)

Florence Tydeman[2]

Alec Miners[3]

Kate Pyper[4]

Adrian R Martineau[5†] (0000-0001-5387-1721)

1, Health Economist, Blizard Institute, Barts and The London School of Medicine and Dentistry, Queen Mary University of London, 4 Newark Street, London E1 2AT

2, Statistician, Blizard Institute, Barts and The London School of Medicine and Dentistry, Queen Mary University of London, 4 Newark Street, London E1 2AT

3, Associate Professor of Health Economics, Department of Health Services Research and Policy, London School of Hygiene and Tropical Medicine, London, UK

4, Statistician, Department of Mathematics and Statistics, University of Strathclyde

5, Professor of Respiratory Infection and Immunity, Institute of Population Health Sciences, Barts and The London School of Medicine and Dentistry, Queen Mary University of London, 4 Newark Street, London E1 2AT

Correspondence to Adrian R Martineau a.martineau@qmul.ac.uk

Abstract

Objective: To determine whether COVID-19 has a significant impact on the adequacy of household income to meet basic needs (primary outcome) and work absence due to sickness (secondary outcome), both at the onset of illness (short-term) and subsequently (long-term).

Design: Multilevel mixed regression analysis of self-reported data from monthly on-line questionnaires, completed 1st May 2020 to 28th October 2021, adjusting for baseline characteristics including age, sex, socioeconomic status and self-rated health.

Setting and Participants: Participants (n=16,910) were UK residents aged 16 years or over participating in a national longitudinal study of COVID-19 (COVIDENCE UK).

Results: Incident COVID-19 was independently associated with increased odds of participants reporting household income as being inadequate to meet their basic needs in the short-term (adjusted odds ratio [aOR) 1.39, 95% confidence interval [CI] 1.12 to 1.73) though this did not persist in the long-term (aOR 1.00, 95% CI 0.86 to 1.16). Exploratory analysis revealed a stronger short-term association amongst those who reported 'long COVID', defined as the presence of symptoms lasting more than 4 weeks after disease onset, than those reporting COVID-19 without 'long COVID' (p for trend 0.002). Incident COVID-19 associated with increased odds of reporting sickness absence from work in the long-term (aOR 4.73, 95% CI 2.47 to 9.06) but not in the short-term (aOR 1.34, 95% CI 0.52 to 3.49).

Conclusions: We demonstrate an independent association between COVID-19 and increased risk of economic vulnerability amongst COVIDENCE participants, measured by both household income sufficiency and sickness absence from work. Taking these findings together with pre-existing research showing that socio-economic disadvantage increases the risk of developing COVID-19, this may suggest a 'vicious cycle' of impaired health and poor economic outcomes.

Trial registration: NCT04330599

Strengths and Limitations of this study

Strengths

- Prospective longitudinal study facilitated identification of temporal relationships between exposures and outcomes.
- Detailed demographic data allowing adjustment for multiple potential confounding factors in multivariable analyses.
- Rich dataset with two indicators of economic vulnerability to corroborate findings.

Limitations

- Rely on self-reported variables including COVID-19 test results and sufficiency of income for household needs.
- Although we obtained a large sample (n=16,910), this was imperfectly representative of the overall UK population.

Introduction

The coronavirus disease 2019 (COVID-19) pandemic has caused global health devastation, with huge mortality and morbidity worldwide. Socioeconomic deprivation was recognised as a major risk factor for incidence and severity of disease prior to the development and roll-out of vaccination against severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), mediated via factors including increased occupational and household SARS-CoV-2 exposure and greater physical vulnerability due to comorbidities.[1],[2],[3] This association persists in the vaccination era, with lower socioeconomic status associated with increased incidence and severity of breakthrough COVID-19.[4] However, the potential for COVID-19 to act as a cause, rather than a consequence, of economic vulnerability has received less research attention, despite the fact that sustained symptoms following an acute episode ('long COVID') are common, with potential to impact negatively on people's daily activities and capacity to work.[5]

One of the challenges in characterising effects of COVID-19 on economic well-being relates to the fact that societal measures to control the spread of COVID-19 are detrimental to employment and economic participation, and may therefore have negative economic impacts even in those who do not experience disease themselves.[1],[6] Pre-pandemic analyses showed a relationship between economic downturns and increased mortality from causes including mental illness, cancer, and postulated 'deaths of despair' arising from suicide, drug overdose, or alcoholism.[7],[8],[9] This relationship is not straightforward, as parallel evidence found a decline in cardiovascular and traffic accident mortality during recessions.[10] Nonetheless, it is likely that pandemic-related economic contractions affect both health and economic wellbeing. The Brookings Institute draws a direct link from economic vulnerability to the COVID-19 pandemic, with particular harms from COVID-19-related poverty observed among populations who were already poor.[11]

In order to dissect out impacts of disease from the consequences of the societal response to the pandemic, we conducted a longitudinal cohort study that was initiated at the start of the pandemic, to determine whether incident COVID-19 was associated with key markers of economic vulnerability. We define economic vulnerability as either the existence or threat of poverty, with the former implying current economic hardship and the latter due to a lack of means to cope with negative economic shocks.[12] We capture these aspects of economic vulnerability through two distinct outcomes. Our primary outcome was self-report of whether household income was sufficient to meet basic needs; this outcome captures individuals who consider themselves below the poverty line due to an adverse event.[13] Our secondary outcome captured participants' ability to earn income working by asking whether individuals who developed COVID-19 were more likely to report absence from work due to sickness. Associations between incident COVID-19 and both outcomes were explored contemporaneously (henceforth 'short-term', i.e. at the time when a positive SARS-CoV-2 test result was reported) and subsequently (i.e. in the long term).

Methods

Study design, setting and participants

COVIDENCE UK is a prospective cohort study (n=16,910) of COVID-19 in the UK population.[14] Its aims are to determine risk factors for incident COVID-19 in the UK population; to characterise the natural history of COVID-19 in the UK population; to evaluate the impact of COVID-19 on the physical, mental, and economic well-being of the UK population; and to provide a resource from which to identify potential participants for future clinical trials of interventions to prevent or treat acute respiratory infections. Leicester South Research Ethics Committee (ref 20/EM/0117) granted full ethics approval, and this study was registered with ClinicalTrials.gov (NCT04330599).

Inclusion criteria were age ≥16 years and UK residence at the point of enrolment. Recruitment was via a national media campaign across print newspapers, radio, television, and online advertising in order to reach a broad sample of the UK population across ages, ethnicities, socioeconomic groups, and other correlates of economic vulnerability. Participants initially completed an online baseline questionnaire capturing COVID-19 status and a wide range of demographic, socioeconomic and clinical characteristics described below. Follow-up questionnaires at monthly intervals captured incidence of RT-PCR- or lateral flow test-confirmed SARS-CoV-2 infection, long-term symptoms of COVID-19 ('long COVID'), and indicators of economic status. The survey comprised a combination of validated demographic questions based on the 2021 UK census,[15] self-reported general health,[16] and other questions developed to specifically capture data relating to COVID-19. These questions were piloted with members of the Patient and Public Involvement Group, across a range of ethnicities and other demographic variables. Specific questions from baseline and monthly questionnaires whose responses contributed data to the current analysis are displayed in Supplementary Table 1 and Supplementary Table 2. The study launched on 1st May 2020, and this paper reports analyses of data collected up to 28th October 2021. All participants who responded to the baseline questionnaire and provided data on SARS-CoV-2 test status and adequacy of household income to meet basic needs in at least one monthly follow-up questionnaire were eligible for inclusion in this analysis.

Exclusion criteria for this analysis were self-report of a positive SARS-CoV-2 test, 'long COVID', or hospitalisation for COVID-19 prior to completion of the baseline questionnaire, and self-report of 'long COVID' in the absence of a positive RT-PCR or lateral flow test result for SARS-CoV-2.

Definition of variables

Our primary outcome variable was self-report of a participant's household income being insufficient to meet their basic needs. This was derived as a binary variable based on responses to the question: "Since you last checked in with us, has your household income been sufficient to cover the basic needs of your household, such as food and heating?". Any answer other than 'yes' (namely: 'no', 'sometimes', or 'mostly') was coded as indicating insufficient income, whilst answering 'yes' was coded as indicating sufficient income. We also considered a secondary outcome associated with economic vulnerability, namely the ability to participate in the workforce. This was represented by a binary variable derived from responses to the question: "Which of the following best describes your current occupational status?". Participants selecting 'not working due to sickness, disability or illness' from a drop-down menu were coded as being absent from work due to sickness.

The following covariates were selected prior to analysis based on their potential to act as confounders of the relationship between incident COVID-19 and study outcomes:[17] age (classified as 'working age' [16-65 years] or 'not working age' [>65 years]), sex (male *vs* female, defined by sex assigned at birth), ethnicity (classified as white or minority ethnic origin), country of residence (England, Scotland, Wales, or Northern Ireland), Index of Multiple Deprivation (IMD) quartile of residential area,[18] baseline occupational status (employed, self-employed, retired, furloughed, unemployed, student, never employed, not working due to sickness/disability/illness, or 'other'), housing status (owns home outright, mortgage holder, private rental, renting from council, or other) and self-reported general health (poor, fair, good, very good, or excellent).

The principal independent variable of interest for our analysis main model was SARS-CoV-2 test positivity. This was defined by a binary indicator where 'yes' included any

self-reported positive lateral flow or RT-PCR SARS-CoV-2 test result, and 'no' included either a self-reported negative lateral flow or RT-PCR SARS-CoV-2 test result or no report of any test taken. Associations between this variable and our two outcomes of interest were considered over two time periods. First, we built a short-term model to examine contemporaneous effects of COVID-19 by asking whether SARS-CoV-2 test positivity was associated with increased risk of reporting insufficient income or sickness absence in the same month as the positive result was recorded. Second, we built a 'long-term' model to test whether a positive SARS-CoV-2 test result was associated with increased risk of reporting insufficient income or sickness absence in subsequent months, excluding the month of infection.

We also conducted two exploratory analyses to determine whether there was a dose-response relationship for associations between COVID-19 severity and risk of reporting insufficient income. This was implemented by categorising participants reporting a positive SARS-CoV-2 test result according to their response to the question "Would YOU say that you currently have 'long COVID', i.e. ongoing symptoms more than four weeks after the onset of proven or suspected COVID-19?". We compared those reporting 'long COVID' and those reporting a positive SARS-CoV-2 test result but no 'long COVID' to those without a positive SARS-CoV-2 test result (the referent category). Second, we categorised participants reporting a positive SARS-CoV-2 test result according to whether or not they were hospitalised, comparing those reporting hospitalisation for COVID-19 and those reporting COVID-19 not requiring hospitalisation to those without a positive SARS-CoV-2 test result (the referent category). Both of these exploratory analyses were conducted for the short-term and long-term models as described above.

Statistical analysis

Multilevel mixed effects logistic regression models were applied to assess the relationship between positive SARS-CoV-2 test results (RT-PCR or lateral flow) and reported insufficient income at any point prior to 28th October 2021 in the main analysis. A random effect of unique participant identifier was included in all models to account for repeated measures, allowing assessment of within-participant variability. These

analyses were adjusted for baseline socio-demographic characteristics as outlined above.

For analyses exploring potential impacts of 'long COVID' and disease precipitating hospitalisation, a random effect for a unique participant identifier was also included to account for repeated measures, with adjustment for baseline characteristics as before, and substitution of the monthly-varying binary principal independent variable indicating SARS-CoV-2 test status with one of the other 3-level key independent variables as previously defined above (i.e. positive SARS-CoV-2 test result with subsequent 'long COVID', positive SARS-CoV-2 test result without 'long COVID' *vs* no positive SARS-CoV-2 test result, OR positive SARS-CoV-2 test result with hospitalisation, positive SARS-CoV-2 test result without hospitalisation *vs* no positive SARS-CoV-2 test result). The models including these 3-level variables were evaluated twice, firstly as standard categorical variables and then secondly exchanging categorical versions for numerical integers, which provided a p-value for trend for 'long COVID' and hospitalisation due to COVID-19 respectively, for both short-term and long-term models. Models for each of these monthly-varying exploratory analyses were built separately from one another, and from the main model which categorised incident COVID-19 as a binary independent variable.

Mixed effects logistic regression models were also applied to assess the relationship between a positive SARS-CoV-2 test result and reported absence from work due to sickness at any point prior to 28th October 2021. The insufficient income variable was not included in this secondary outcome model, and 'long COVID' and hospitalisation were also not considered. Missing data were assumed to be missing completely at random (MCAR) and were handled with listwise deletion in the generalised linear mixed models so that unbiased estimates were obtained. All statistical analyses were conducted using R version 4.1.1 with the mixed effects models conducted using R-package `lmer4`.

Sub-group analyses

We tested for effect modification by including interaction terms for SARS-CoV-2 test positivity and age (categorised as ≤65 or >65 years) and sex (categorised as male or

female at birth) in multivariable models investigating determinants of our primary outcome.

Patient and public involvement

Three patient and public involvement representatives were involved in development of the research questions and the choice of outcome measures specified in the study protocol. One of them also led on development and implementation of strategies to maximise participant recruitment. Results of work will be disseminated to individual participants via a webinar.

Results

19,980 participants completed the COVIDENCE UK baseline questionnaire between 1st May 2020 and 29th October 2021, of whom 1,412 did not complete any subsequent monthly questionnaire. Of the remaining 18,568 participants, 16,910 (91.2%) contributed data to the current analysis. Reasons for exclusion of the 1,658 participants who did not contribute data to this analysis are detailed in the participant flow diagram (Supplementary Appendix Figure S1). Table 1 presents baseline characteristics of participants contributing data to this analysis: their median age was 63 years, 69.8% were female, 94.7% were of White ethnic origin, 2.7% were receiving universal credit payments, 6.9% reported their household income as being 'sometimes', 'mostly' or 'not' sufficient to meet their basic needs in the month prior to enrolment, and 1.7% reported not working due to sickness. Figure 1 illustrates response flows in sufficiency of income to meet basic household needs over time.

Table 1: Participant characteristics at baseline

		Number Participants (%)
Sex	Male	5106 (30.2%)
	Female	11,804 (69.8%)
Working age	Yes (16-65)	10,338 (61.1%)
	No	6570 (38.9%)
Ethnicity	Minority ethnic	894 (5.3%)
	White	16,015 (94.7%)
Country	Scotland	1029 (6.1%)
	Wales	604 (3.6%)
	Northern Ireland	314 (1.9%)

	England	14,956 (88.4%)
IMD Quartile	1 (most deprived)	3990 (23.6%)
	2	4191 (24.8%)
	3	4299 (25.4%)
	4 (least deprived)	4410 (26.1%)
Claiming universal credit	Yes	464 (2.7%)
	No	16,390 (96.9%)
Occupation	Self-employed	1554 (9.2%)
	Retired	7547 (44.6%)
	Furloughed	386 (2.3%)
	Unemployed	296 (1.8%)
	Student	345 (2.0%)
	Other	394 (2.3%)
	Never Employed	10 (0.01%)
	Not working due to sickness	281 (1.7%)
	Employed	6097 (36.1%)
Housing	Mortgage	4250 (25.1%)
	Private Renting	1227 (7.3%)
	Renting Council	531 (3.1%)
	Other	724 (4.3%)
	Owns home	10,174 (60.2%)
Self-reported general health	Poor	480 (2.8%)
	Fair	1808 (10.7%)
	Good	4537 (26.8%)
	Very good	6691 (39.6%)
	Excellent	3394 (20.1%)
Income sufficient to cover basic needs	Yes	15,749 (93.1%)
	Mostly	617 (3.6%)
	Sometimes	147 (0.9%)
	No	396 (2.3%)

1 Missing data: working age (N = 2, 0.01%), ethnicity (N = 1, <0.01%), country (N = 7, 0.04%), IMD quartile (N = 20, 0.12%), housing (N = 4, 0.02%), universal credit (N = 56, 0.3%), income sufficient (N = 1,<0.01%).

A total of 1,120 participants reported a positive SARS-CoV-2 test result at least once between enrolment and the end of follow-up (28th October 2021). Of these, 39/1120 (3.5%) were hospitalised for COVID-19, and 308/1120 (27.5%) reported 'long COVID'. A total of 7310/16,910 (43.3%) participants reported insufficient income on one or more occasions and 398/16,910 (2.4%) reported absence from work due to sickness on one or more occasions during follow-up (Supplementary Table 3).

Incident COVID-19 was independently associated with increased odds of participants reporting household income as being inadequate to meet their basic needs in multivariable analyses in the short-term (aOR 1.39, 95% CI 1.12 to 1.73) though this did not persist in the long-term (aOR 1.00, 95% CI 0.86 to 1.16) (Table 2). Of the eight

covariates included in each model, independent associations with increased risk of reporting insufficient income were also seen for non-White vs White ethnicity, younger vs older age (≤65 vs >65 years), higher vs lower deprivation quartile, poorer vs better health at baseline, being self-employed, furloughed, other (including sick) or unemployed vs being employed at baseline, and having a mortgage, privately renting, or renting from the council vs owning their home outright. Neither sex nor age modified the association between SARS-CoV-2 test-positivity and reporting insufficient income (for sex, P for interaction = 0.23 and 0.51 for short-term and long-term models, respectively; for age, P for interaction =0.48 and 0.14 for short-term and long-term models, respectively).

Table 2: Determinants of reporting insufficient income during follow-up

		Short-term Responses		Long-term Responses	
Variable	Response	Adjusted OR (95% CI)	P	Adjusted OR (95% CI)	P
Incident COVID-19	Yes	1.39 (1.12 to 1.73)	0.002	1.00 (0.86 to 1.16)	0.977
	No	1.00	-	1.00	--
Sex	Male	1.03 (0.90 to 1.11)	0.548	1.03 (0.93 to 1.15)	0.564
	Female	1.00	-	1.00	-
Age, years	16-65	1.63 (1.41 to 1.87)	<0.001	1.59 (1.39 to 1.83)	<0.001
	>65	1.00	-	1.00	-
Ethnicity	Minority ethnic	1.83 (1.49 to 2.27)	<0.001	1.85 (1.49 to 2.27)	<0.001
	White	1.00	-	1.00	-
Country	Scotland	1.01 (0.80 to 1.28)	0.916	1.01 (0.80 to 1.28)	0.942
	Wales	0.82 (0.61 to 1.09)	0.164	0.82 (0.61 to 1.10)	0.187
	Northern Ireland	0.91 (0.62 to 1.31)	0.588	0.91 (0.63 to 1.32)	0.611
	England (ref)	1.00	-	1.00	-
IMD Quartile	1 (most deprived)	1.51 (1.27 to 1.79)	<0.001	1.37 (1.17 to 1.60)	<0.001
	2	1.26 (1.10 to 1.44)	<0.001	1.20 (1.06 to 1.4536)	0.005
	3	1.04 (0.91 to 1.20)	0.535	1.04 (0.91 to 1.18)	0.571
	4 (least deprived, ref)	1.00	-	1.00	-
Occupation	Self-employed	1.73 (1.45 to 2.06)	<0.001	1.84 (1.54 to 2.19)	<0.001
	Retired	0.63 (0.55 to 0.72)	0.031	0.82 (0.71 to 0.96)	0.013
	Furloughed	2.18 (1.60 to 2.97)	<0.001	2.17 (1.59 to 2.96)	<0.001
	Unemployed	7.76 (5.50 to 11.0)	<0.001	7.66 (5.43 to 10.83)	<0.001
	Student	1.15 (0.81 to 1.64)	0.558	1.12 (0.78 to 1.59)	0.549
	Other/never employed/sick	2.08 (1.59 to 2.62)	<0.001	2.07 (1.61 to 2.66)	<0.001
	Employed (ref)	1.00	-	1.00	-
Housing	Mortgage	1.66 (1.45 to 1.89)	<0.001	1.53 (1.34 to 1.74)	<0.001
	Private Renting	4.55 (3.75 to 5.53)	<0.001	4.35 (3.58 to 5.28)	<0.001
	Renting Council	11.6 (8.81 to 15.30)	<0.001	11.5 (8.72 to 15.10)	<0.001
	Other	2.94 (2.28 to 3.79)	<0.001	2.77 (2.15 to 3.57)	<0.001
	Owns home (ref)	1.00	-	1.00	-
Self-reported general health	Poor	5.32 (3.94 to 7.18)	<0.001	5.38 (3.98 to 7.26)	<0.001
	Fair	3.41 (2.84 to 4.09)	<0.001	3.47 (2.88 to 4.14)	<0.001
	Good	1.98 (1.72 to 2.29)	<0.001	2.01 (1.74 to 2.33)	<0.001
	Very good	1.21 (1.06 to 1.39)	0.003	1.23 (1.07 to 1.40)	0.003
	Excellent (ref)	1.00	-	1.00	-

To explore these findings further, we investigated whether associations between incident COVID-19 and income insufficiency were stronger for the subset of participants who either reported 'long COVID' or who were hospitalised for COVID-19 treatment. Results are shown in Table 3: point estimates for adjusted ORs in the short-term model were higher for those who reported 'long COVID' or hospitalisation than for those who did not (P values for trend 0.002 for both 'long COVID' and hospitalisation). We also note clinical interest in the direction of association shown in the long-term 'long COVID' model (aOR 1.26, 95% CI 0.98 to 1.61) with a confidence interval crossing 1 but leaning in positive direction.

Table 3: Impact of self-reported 'long COVID' and hospitalisation for COVID-19 on reporting insufficient income during follow-up

		Short-term Responses		Long-term Responses	
Variable	Response	Adjusted OR (95% CI)	P	Adjusted OR (95% CI)	P
Self-report 'long COVID'	No COVID-19 (ref)	1.00	-	1.00	-
	COVID-19, no 'long COVID'	1.44 (1.15 to 1.80)	0.003	0.90 (0.75 to 1.08)	0.263
	'Long COVID'	1.50 (1.14 to 1.95)	0.002	1.26 (0.98 to 1.61)	0.067
	P for trend	-	0.002	-	0.477
Hospitalisation due to COVID-19	No COVID-19 (ref)	1.00	-	1.00	-
	COVID-19, not hospitalised	1.37 (1.10 to 1.71)	0.002	0.99 (0.85 to 1.16)	0.942
	COVID-19, hospitalised	1.91 (0.694 to 5.25)	0.220	1.38 (0.69 to 2.78)	0.365
	P for trend	-	0.002	-	0.902

2 Multivariable regression models fully adjusted for the following baseline variables: sex, age, ethnicity, country, IMD quartile, occupation, housing and self-reported general health.

Finally, we examined whether incident COVID-19 was associated with our secondary outcome of absence from work due to sickness. Results are presented in Table 4: incident COVID-19 was associated with increased odds of reporting sickness absence from work in the long-term (aOR 4.73, 95% CI 2.47 to 9.06) but not in the short-term (aOR 1.34, 95% CI 0.52 to 3.49).

Table 4: Determinants of reporting 'not working due to sickness' during follow-up

		Short-term Response		Long-term Response	
Variable	Response	Adjusted OR (95% CI)	P	Adjusted OR (95% CI)	P
Incident COVID-19	Yes	1.34 (0.52 to 3.49)	0.54	4.73 (2.47 to 9.06)	<0.001
	No	1.00	-	1.00	
Sex	Male	0.58 (0.52 to 2.24)	0.433	0.58 (0.15 to 2.24)	0.427
	Female (ref)	1.00	-	1.00	-
Working age	Yes (16-65)	14.5 (1.57 to 134.0)	0.018	13.82 (1.48 to 129.30)	0.021
	No (ref)	1.00	-	1.00	-
Ethnicity	Minority ethnic	0.76 (0.08 to 6.75)	0.814	0.75 (0.15 to 11.53)	0.805
	White (ref)	1.00	-	1.00	-
Country	Scotland	0.44 (0.04 to 5.03)	0.508	0.47 (0.04 to 5.51)	0.550
	Wales	0.98 (0.07 to 14.80)	0.992	0.95 (0.06 to 14.64)	0.972
	Northern Ireland	0.59 (0.03 to 12.11)	0.731	0.57 (0.03 to 12.25)	0.717
	England (ref)	1.00	-	1.00	-
IMD Quartile	1 (most deprived)	1.59 (0.31 to 8.24)	0.587	1.57 (0.30 to 8.28)	0.594
	2	1.06 (0.21 to 5.29)	0.948	1.08 (0.21 to 5.46)	0.923
	3	1.03 (0.19 to 5.49)	0.970	1.02 (0.19 to 5.47)	0.986
	4 (least deprived, ref)	1.00	-	1.00	-
Housing	Mortgage	0.76 (0.19 to 3.07)	0.702	0.74 (0.18 to 3.00)	0.671
	Private Renting	1.60 (0.30 to 8.64)	0.587	1.58 (0.29 to 8.58)	0.595
	Renting Council	8.62 (1.96 to 37.8)	0.004	8.56 (1.92 to 38.19)	0.005
	Other	1.56 (0.22 to 11.1)	0.042	1.53 (0.21 to 10.98)	0.673
	Owns home (ref)	1.00	-	1.00	-
Self-reported general health	Poor	94.6 (5.82 to 1540.0)	0.001	101.80 (6.13 to 1689.72)	0.001
	Fair	17.6 (1.12 to 276.0)	0.042	17.93 (1.12 to 287.80)	0.042
	Good	3.86 (0.23 to 66.0)	0.352	3.94 (0.23 to 68.90)	0.348
	Very good	2.24 (0.12 to 40.8)	0.587	2.28 (0.12 to 42.57)	0.580
	Excellent (ref)	1.00	-		-

Discussion

To our knowledge, this study is the first to investigate the impact of COVID-19 on subsequent risk of becoming economically vulnerable. We report that incident COVID-19 was independently associated with increased risk of participants reporting insufficient household income in the short-term, though not in the long-term. This increased odds in the short-term model equates to a 32% increase in risk when the aOR is converted to an adjusted risk ratio (aRR 1.32, 95% CI 1.10 to 1.58). The short-term association was stronger where COVID-19 precipitated 'long COVID' or hospitalisation, supporting causal interpretation. Incident COVID-19 was also associated with increased risk of participants reporting absence from work due to sickness in the long-term.

Our findings accord with those of studies that have investigated the impact of other infectious diseases on economic outcomes. People living with HIV have been reported to experience higher rates of severe poverty, employment loss and impaired physical and mental functioning.[19],[20],[21] Similar analyses revealed a link between tuberculosis and increased poverty in both the UK and India.[22],[23] However, these studies were all cross-sectional in design, leaving uncertainty as to whether the diseases in question were a cause or consequence of the observed poverty.

Our analysis aimed to identify whether there is evidence of an association between these outcomes in a specific direction of causality, i.e. from disease to economic vulnerability. The prospective design employed in the current study was valuable to this end, as it allowed us to focus on the timing of onset of the relationship between incident COVID-19 and subsequent economic vulnerability. Demonstration of a dose-response relationship between severity of COVID-19 and the primary outcome, along with consistency of association for two different measures of economic vulnerability (inadequate income and sickness absence) both strengthen the case for causal interpretation.[24]

Taking these findings together with other research showing that socio-economic disadvantage increases the risk of developing COVID-19,[1],[2],[3],[4] our current study represents an important advance by indicating that the relationship between COVID-19 and socio-economic deprivation may be bi-directional. This suggests a 'vicious cycle' of

poor health and economic vulnerability which individuals could be pushed into, or accelerated along, by COVID-19. The poorer someone was, is the more likely they were to fall sick. If they did fall sick, they were more likely to experience poverty during the pandemic, with further health risks.

It is notable that incident COVID-19 had a significant negative impact on self-assessed adequacy of household income in the short-term, whereas the impact on work absence due to sickness was only evident in the long-term. One potential reason for this is that those ill with COVID-19 would still self-classify as 'employed' but on temporary leave in the short-term, whilst persistent COVID-19 symptoms might lead to a change in status to official sickness absence. This raises the possibility that COVID-19 may impact economic vulnerability through multiple mechanisms including non-employment-based mechanisms in the short term, such as increased health-related costs, and employment-based mechanisms in the longer term. Early, decisive policy interventions could help prevent this potential vicious cycle, with employment advice and other economic support offered alongside healthcare follow-up at hospital discharge.

Our study has several strengths. Its large size afforded ample power to detect potential impacts of COVID-19 on our primary and secondary outcomes, while its population-based recruitment and prospective design maximises generalisability of our findings while allowing us to characterise temporal relationships between exposures and outcomes. Detailed characterisation of participants allowed us to adjust for multiple potential confounding factors in multivariable analyses, and to explore two different indicators of economic vulnerability.

This work also has limitations. First, the variables of interest are all self-reported, including both SARS-CoV-2 test results and indicators of economic vulnerability. Participants were unaware of the hypotheses tested in this work, however, reducing potential for reporter bias to operate. We also relied on reports of voluntary tests, which allows the possibility that some COVID-positive individuals did not receive a test and thus were treated as negative. However, testing was readily available and mandatory for many workplaces and all individuals with symptoms throughout the study period. Participant exclusion criteria also included "self-report of 'long COVID' in the absence of

a positive RT-PCR or lateral flow test result for SARS-CoV-2". This minimises the likelihood of a symptomatic individual classified as test-negative. Nonetheless, some with asymptomatic infection may still have been misclassified.

Second, the study population was not perfectly representative of the adult UK population as a whole: males, younger people, people of minority ethnic origin and those with lower educational attainment were all under-represented. Limitations of non-random sampling include potential undetected sampling error, selection bias, or motivation bias of participants to engage with the study. Caution is therefore required when extrapolating conclusions beyond the sample population. Further, internet access was a prerequisite to take part, which could limit generalisability of results particularly amongst the most economically deprived. While this may have limited our power to detect associations within sub-groups, we highlight that representativeness is not necessarily a barrier to identification of causal associations in observational epidemiology.[25]

Fourth, we acknowledge that the precise order of COVID-19 and economic events cannot be guaranteed by our short-term model. We cannot rule out the theoretical possibility that a negative economic shock in the same month preceded COVID infection for some individuals. Nonetheless, this is unlikely to drive the majority of the effect identified, as we do not see a plausible mechanism for an economic shock to precipitate COVID-19 infection in a matter of days. The reverse relationship, where infection precedes economic vulnerability, remains more plausible. We also note that the findings of this short-term model are consistent with both the 'long COVID' and long-term sickness absence models, which increases confidence that COVID-19 infection preceded economic vulnerability for the vast majority of participants considered.

Finally, as with any observational study, residual or unmeasured confounding cannot be ruled out as an explanation for the associations we observe. We handled missing data under the assumption that survey data were missing at random, but it is possible that data were more likely to be missing if someone had COVID-19 or became economically vulnerable. In the most extreme case, fatal or very severe COVID-19 would prevent questionnaire completion; alternatively, someone may have become ill or lost their job

then no longer have the cognitive or physical capacity to complete the questionnaires. Conversely, it is possible that SARS-CoV-2 test positivity may have increased the likelihood of participants completing their monthly follow-up questionnaires.

Our findings highlight the need for further research in three areas. First, analogous studies should be done in other populations to determine whether our findings can be replicated; ideally such studies should capture details of longitudinal earnings to introduce greater objectivity and quantification of impacts while reducing reporting bias. Second, further work is needed to understand the specific mechanisms by which COVID-19 may lead to economic vulnerability, investigating the relative importance of factors including lost employment, 'long COVID' symptoms and stigmatisation. Third, our findings suggest the need for further work to explore bi-directional relationships between illness and deprivation more generally.

In conclusion, we report independent associations between incident COVID-19 and subsequent development of economic vulnerability, exposing a previously hidden human cost of the pandemic. Our findings have potentially significant policy implications, given the economic imperative to plan COVID-19-related spending in the most efficient way possible. While a 'vicious cycle' of sickness and poverty presents a major threat to wellbeing, its recognition could also offer an opportunity for effective, early-stage circuit-breaker interventions with potential to avert greater costs in the future.

Ethics Approval Statement

COVIDENCE UK was sponsored by Queen Mary University of London and approved by Leicester South Research Ethics Committee (ref 20/EM/0117). It is registered with ClinicalTrials.gov (NCT04330599).

Contributorship Statement

The corresponding author attests that all listed authors meet all four ICMJE authorship criteria and that no others meeting the criteria have been omitted. Adrian Martineau planned and conducted the COVIDENCE UK study. Anne Williamson, Florence Tydeman, and Adrian Martineau wrote the original draft, and Kate Pyper and Alec Miners contributed key intellectual content and critical revisions. Florence Tydeman and Kate Pyper carried out the statistical analyses. All authors approved the final version for publication. The corresponding author affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as originally planned (and, if relevant, registered) have been explained.

Competing Interests

All authors have completed the ICMJE uniform disclosure form at http://www.icmje.org/disclosure-of-interest/ and declare: this study was supported by a grant from Barts Charity to ARM (MGU0466). The funder had no role in any aspect of the study design; in the collection, analysis, and interpretation of data; in the writing of the report; or in the decision to submit the article for publication. We confirm the independence of researchers from funders and that all authors, external and internal, had full access to all of the data (including statistical reports and tables) in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis.

Funding

Barts Charity MGU0466

Data Sharing Statement

De-identified participant data will be made available upon reasonable request to Prof Martineau (a.martineau@qmul.ac.uk), subject to terms of Research Ethics Committee approval and Sponsor requirements.

References

1. Blundell R, Costa Dias M, Joyce R, Xu X. COVID-19 and Inequalities. *Fiscal Studies*. 2020; 41(2); 291-319.
2. Holt H, Talaei M, Greenig M*, et al.* Risk factors for developing COVID-19: a population-based longitudinal study (COVIDENCE UK). *Thorax* Epub ahead of print: 30 November 2021. doi: 10.1136/thoraxjnl-2021-217487
3. Ahmed F, Ahmed N, Pissarides C, Stiglitz J. Why inequality could spread COVID-19. *The Lancet Public Health.* 2020; 5(5); e240.
4. Antonelli M, Penfold RS, Merino J, et al. Risk factors and disease profile of post-vaccination SARS-CoV-2 infection in UK users of the COVID Symptom Study app: a prospective, community-based, nested, case-control study. *The Lancet Infectious Diseases*. 2022; 22(1); 43-55.
5. NHS Employers. *Supporting recovery after long COVID.* 2021. Available from: https://www.nhsemployers.org/articles/supporting-recovery-after-long-covid
6. De Vos J. The effect of COVID-19 and subsequent social distancing on travel behaviour. *Transportation Research Interdisciplinary Perspectives.* 2020; 5.
7. Burgard, S.A. and Kalousova, L.. Effects of the Great Recession: Health and well-being. *Annual Review of Sociology*. 2015; 41, pp.181-201.
8. Deaton A, Case A. *Deaths of Despair and the Future of Capitalism.* Princeton: Princeton University Press; 2020.
9. Friebel, R., Yoo, K.J. and Maynou, L.. Opioid abuse and austerity: evidence on health service use and mortality in England. *Social Science & Medicine*. 2022; 298, p.114511.
10. Strumpf, E.C., Charters, T.J., Harper, S. and Nandi, A.. Did the Great Recession affect mortality rates in the metropolitan United States? Effects on mortality by age, gender and cause of death. *Social Science & Medicine*. 2017; 189, pp.11-16.
11. Graham C. The human costs of the pandemic: Is it time to prioritize well-being? *Brookings Institute*. 2020. Available from: https://www.brookings.edu/research/the-human-costs-of-the-pandemic-is-it-time-to-prioritize-well-being/ [Accessed 14th December 2021].
12. Dercon S. Vulnerability: a micro perspective. *Securing development in an unstable world: Annual World Bank Conference on Development Economics*. 2006, pp.117-146.
13. Chaudhuri, S. Assessing vulnerability to poverty: Concepts, empirical methods and illustrative examples. *Department of Economics, Columbia University, New York.* 2003. Available from: http://econdse.org/wp-content/uploads/2012/02/vulnerability-assessment.pdf
14. Talaei M, Faustini S, Holt H, *et al.* Determinants of pre-vaccination antibody responses to SARS-CoV-2: a population-based longitudinal study (COVIDENCE UK). *BMC Med* 2022; 20 **(**87). doi: 10.1186/s12916-022-02286-4.
15. Office for National Statistics. Approach and processes for assuring the quality of the 2021 Census data. Available from:

https://www.ons.gov.uk/census/censustransformationprogramme/approachandprocessesforassuringthequalityofthe2021censusdata

16. Ganna A, Ingelsson E. 5 year mortality predictors in 498 103 UK Biobank participants: a prospective population-based study. *The Lancet.* 2015; 383(9993), pp. 533-540.
17. Van der Weele T. Principles of confounder selection. *Eur J Epidemiol.* 2019; 34(3); 211-219.
18. Ministry of Housing, Communities and Local Government. The English Indices of Deprivation 2019. 2019. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/853811/IoD2019_FAQ_v4.pdf
19. National AIDS Trust. Extreme poverty among people with HIV in the UK increasing. 2010. Available from: https://www.nat.org.uk/press-release/extreme-poverty-among-people-hiv-uk-increasing
20. Dray-Spira R, Gueguen A, Lert F, VESPA Study Group. Disease severity, self-reported experience of workplace discrimination and employment loss during the course of chronic HIV disease: differences according to gender and education. *Occupational and environmental medicine*. 2008; 65(2); 112–119.
21. APA. HIV/AIDS and Socioeconomic Status. *American Psychological Association.* 2010. Available from: https://www.apa.org/pi/ses/resources/publications/hiv-aids
22. Spence D, Hotchkiss J, Williams C, Davies P. Tuberculosis and poverty. *British Medical Journal.* 1993; 307; 759-761.
23. Rajeswari R, Balasubramanian R, Muniyandi M, Geetharamani S, Thresa X, Venkatesan P. Socio-economic impact of tuberculosis on patients and family in India. *Int J Tuberc Lung Dis.* 1999; 3(10); 869-77.
24. Hill A. The Environment and Disease: Association or Causation?. *Proceedings of the Royal Society of Medicine*. 1965; 58 (5): 295–300.
25. Rothman KJ, Gallacher JEJ, Hatch EE. Why representativeness should be avoided. *International Journal of Epidemiology*. 2013; 42(4); 1012–1014.

Figure 1: Sankey diagram illustrating response flows in sufficiency of income to meet basic household needs over time.

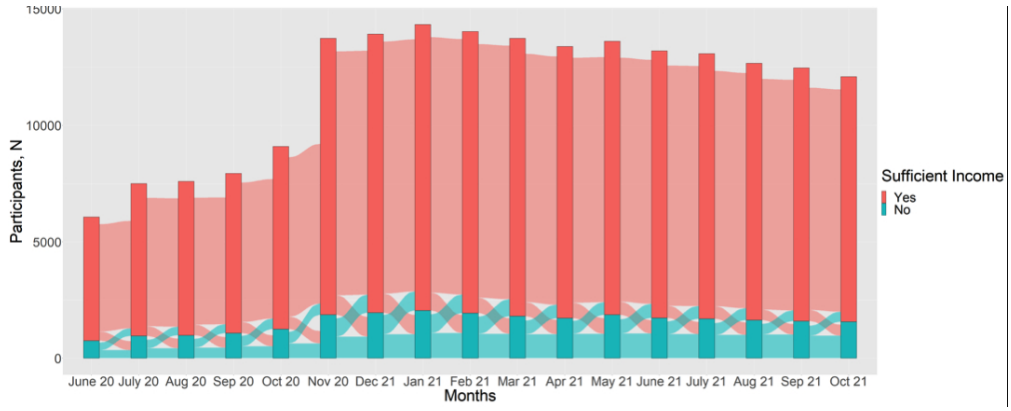


Figure 1: Sankey diagram illustrating response flows in sufficiency of income to meet basic household needs over time.

462x185mm (59 x 59 DPI)

Short- and long-term impacts of COVID-19 on economic vulnerability: a population-based longitudinal study (COVIDENCE UK)

Supplementary Material

Table S1: Baseline questionnaire

Sociodemographic	
Date of birth (DD/MM/YYYY)	
Date of questionnaire (DD/MM/YYYY)	
Post code	
Please state your **assigned sex at birth.**	-Male -Female
What is your ethnic origin?	- White - English / Welsh / Scottish / Northern Irish / British - Irish - Gypsy or Irish Traveller - Any other white background - Mixed / Multiple ethnic groups - White and Black Caribbean - White and Black African - White and Asian - Any other Mixed / Multiple ethnic backgrounds - Asian / Asian British - Indian - Pakistani - Bangladeshi - Chinese - Any other Asian background - Black / African / Caribbean / Black British - African - Caribbean - Any other Black / African / Caribbean background - Arab - Other Ethnic Group
In the last month, was your household income sufficient to cover the basic needs of your household, such as food and heating?	- Yes - Mostly - Sometimes - No
Please select the box that best describes your current housing situation:	- I own my home outright - I own my home and I am paying a mortgage - I am renting privately - I am renting from the council/housing association - I am staying with friends or family - I am homeless or living in temporary accommodation - Other
Do you currently claim Universal Credit?	- Yes, I have applied to receive Universal Credit but have **not yet** received any payments - Yes, I have claimed Universal Credit and received **one or more** payments - No
Which of the following best describes your current occupational status?	- Employed - Self-employed - Retired - Furloughed - Unemployed - Student - Never employed - Not working due to sickness/disability or illness - Other
Over the last 12 months, would you say that on the whole, your health has been:	- Excellent - Very good - Good - Fair - Poor
Since February 1st 2020, have you had a nose/throat swab to test for COVID-19?	- Yes - No
On what date did you have this nose/throat swab? If you are not sure of the exact date, enter the approximate date (DD/MM/YYYY).	

e.g. 25/04/2020	
What was the result?	- Positive - Negative - Not known

Table S2: Monthly follow-up questionnaire

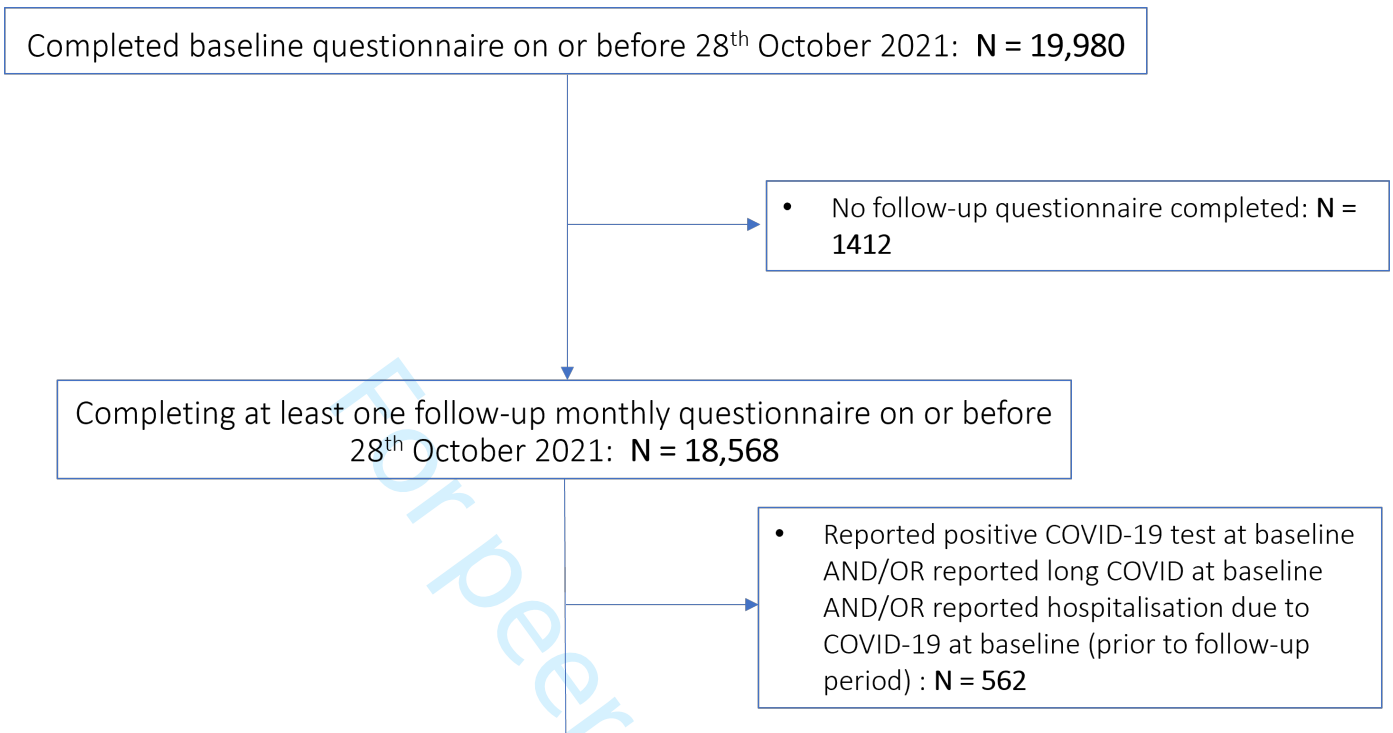
Questions asked at every monthly follow-up	
Since you last checked in with us, have you had a nose or throat swab for COVID-19 or any other respiratory virus, or has a result from a previous swab test become newly available?(This question is about tests to detect the virus itself: they are usually done in somebody who has symptoms, but screening of asymptomatic people can also be done. It's usually a nose/throat swab, but saliva tests are also becoming available)	- Yes - No
On what date did you have this nose / throat swab? If you are not sure of the exact date, enter the approximate date (DD/MM/YYYY).	
What was the result? Click as many as apply.	- Positive for COVID-19 (SARS-CoV-2 coronavirus) - Positive for influenza virus - Positive for another respiratory virus - Negative for all/any viruses tested - Not Known
Did you go to hospital for treatment of these symptoms?	- Yes, and I was admitted to hospital (i.e. I spent one or more nights as a hospital in-patient) - Yes, I attended a hospital accident and emergency department but I was not admitted to hospital (i.e. I went home without spending one or more nights as a hospital in-patient) - No, I didn't go to hospital for treatment of these symptoms
What did the hospital doctors diagnose?	- Suspected or proven COVID-19 - Something else
Would YOU say that you currently have 'long COVID', i.e. ongoing symptoms more than four weeks after the onset of proven or suspected COVID-19?	- Yes - No - Don't know/not sure
Since you last checked in with us, has your household income been sufficient to cover the basic needs of your household, such as food and heating?	- Yes - Mostly - Sometimes - No
Has your employment status changed since you last checked in with us?	- Yes - No
Which of the following best describes your current occupational status?	- Employed - Self-employed - Retired - Furloughed - Unemployed - Student - Never employed - Not working due to sickness/disability or illness - Other

Table 3: Summary of participant response numbers for monthly-varying independent and dependent variables

	Reponses	Number Participants (%)
Dependent Variables		
Income sufficient	No	7310 (43.3%)
	Yes	9600 (64.7%)
Not working due to sickness	Yes	398 (2.4%)
	No	16,512 (97.6%)
Independent Variables		
Incident COVID-19	Yes	1120 (6.6%)
	No	15,790 (93.4%)
Self-reported 'long COVID'	'Long COVID'	308 (1.8%)
	COVID-19, never 'long COVID'	812 (4.8%)
	No COVID-19	15,790 (93.4%)
Hospitalisation due to COVID-19	COVID-19, hospitalised	39 (0.2%)
	COVID-19, never hospitalised	1089 (6.5%)
	No COVID-19 (ref)	15,782 (93.3%)

1Participant numbers are reported here based on whether they EVER report the answer of interest during follow-up. For income sufficiency, they are coded as 'no' if they answer 'no', 'sometimes' or 'mostly' at least once during follow-up. For sickness absence, incident COVID-19, 'long COVID', and hospitalisation, they are coded as 'yes' if they 'yes' for the relevant variable at least once during follow-up.

Figure S1: Participant flow diagram



STROBE Statement

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	5
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	n/a
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6
Bias	9	Describe any efforts to address potential sources of bias	8
Study size	10	Explain how the study size was arrived at	9
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	8
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	8
		(*e*) Describe any sensitivity analyses	7-8

Continued on next page

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	9
		(c) Consider use of a flow diagram	Supp Fig 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	9, Supp Table 3
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	9
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	Supp Table 3
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	*n/a*
		Cross-sectional study—Report numbers of outcome events or summary measures	*n/a*
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6, 17-19
		(*b*) Report category boundaries when continuous variables were categorized	17, 19
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10
Discussion			
Key results	18	Summarise key results with reference to study objectives	10-11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11
Generalisability	21	Discuss the generalisability (external validity) of the study results	12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.