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# A comprehensive characterisation of patients diagnosed with post-COVID-19 condition in Sweden 16 months after the introduction of the ICD-10 diagnosis code (U09.9): a population-based cohort study

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**Highlights**

- In a population-based dataset, 2.0% of COVID-19 patients had PCC
- The cumulative incidence was higher among women compared to men (2.3% vs 1.6%)
- Among hospitalised (intensive care) COVID-19 patients (n=2,509), 36.9% had PCC
- Among non-hospitalised COVID-19 patients (n=478,241), 1.5% had PCC
- Compared to patients without PCC, they were older and had a tertiary education

**Key words:** Cohort study, COVID-19, post COVID-19 condition, Population health, Epidemiology

## Abstract

**Background**

The objective of this study was to provide a comprehensive characterisation of patients diagnosed with post-COVID-19 condition (PCC) during the first 16 months of usage of the International Classification of Diseases revision 10 (ICD-10) diagnosis code U09.9 in Sweden.

**Methods**

We used data from national registers and primary healthcare databases for all adult inhabitants of the two largest regions in Sweden, comprising 4.1 million inhabitants (approximately 40% of the Swedish population). We present the cumulative incidence and incidence rate of PCC overall and among subgroups and describe COVID-19 patients with or without PCC regarding sociodemographic characteristics, comorbidities, subsequent diseases, COVID-19 severity, and virus variants.

**Findings**

Of all registered COVID-19 cases available for PCC diagnosis (n=506,107), 2.0% (n=10,196) had been diagnosed with PCC using ICD-10 code U09.9 as of 15 February 2022 in the two largest regions in Sweden. The cumulative incidence was higher among women compared to men (2.3% vs 1.6%, p<0.001). The majority of PCC cases (n=7,162, 70.2%) had not been hospitalised for COVID-19. This group was more commonly female (69.9% vs 52.9%, p<0.001), had a tertiary education (51.0% vs 44.1%, p<0.001), and was older (median age difference 5.7 years, p<0.001) compared to non-hospitalised COVID-19 patients without PCC.

**Interpretation**

This characterisation furthers the understanding of patients diagnosed with PCC and could support policymakers with appropriate societal and healthcare resource allocation.

## Introduction

Two years into the COVID-19 pandemic, many questions remain regarding patients with prolonged symptoms after SARS-CoV-2 infection. Although several studies have described post COVID-19 complications and symptoms in different settings and populations (Ayoubkhani et al., 2021, Blomberg et al., 2021, Havervall et al., 2021, Tran et al., 2022, Westerlind et al., 2021), it is difficult to compare results and draw conclusions due to the substantial heterogeneity between studies (Michelen et al., 2021). Discriminating between post-COVID-19 complications, prolonged symptoms of the acute COVID-19 infection, or consequences of possible hospital care, including post-intensive care syndrome (Rawal et al., 2017), can be difficult as the clinical presentations may overlap. Furthermore, the terminology of the condition still varies and a widely accepted definition has been lacking (Centers for Disease Control and Prevention, 2021b, National Institute for Health and Care Excellence, 2020). The World Health Organization (WHO) recently produced a consensus clinical case definition based on a Delphi process. The term "post-COVID-19 condition" (PCC) was defined as a condition that "occurs in individuals with a history of probable or confirmed SARS-CoV-2 infection, usually three months from the onset, with symptoms that last for at least two months and cannot be explained by an alternative diagnosis" (Soriano et al., 2022). Similarly to acute COVID-19, the symptoms and severity of PCC vary widely among affected individuals and can involve multiple organ systems (Crook et al., 2021). PCC can be used to describe the various complications arising from the acute infection, as well as a condition characterised by post-viral fatigue. Commonly reported symptoms of PCC include fatigue,

dyspnoea, cognitive impairment, headache, muscle pain, and cardiac abnormalities such as chest pain and palpitations (Crook et al., 2021, Groff et al., 2021, National Institute for Health and Care Excellence, 2020, Soriano et al., 2022). The underlying processes of PCC are not fully understood, but various mechanisms for the different symptoms have been proposed, including virus-specific pathophysiologic changes, damage from the inflammatory response to the acute infection, expected sequelae of post-critical illness (Nalbandian et al., 2021), and neuroinflammatory responses in the brain (Eden et al., 2022, Kanberg et al., 2021, Song et al., 2021). The condition has been reported in patients previously hospitalised for acute COVID-19 as well as in patients with mild acute disease (Augustin et al., 2021, Ayoubkhani et al., 2021). Several studies have described PCC as more common in females than males (Augustin et al., 2021, Huang C. et al., 2021) and the condition does not seem to be restricted to the elderly (Ayoubkhani et al., 2021, Daugherty et al., 2021).

In September 2020, just over a year before the Delphi consensus definition was released, the WHO introduced the PCC diagnosis code (U09.9) within the International Classification of Disease revision 10 (ICD-10), and it was quickly adopted in the Swedish version (World Health Organization, 2020a, 2020b). However, some countries including the UK are instead using the emergency code U07.4 (NHS Digital, 2021) and it was not until October 2021 that the code U09.9 was introduced in the US (Centers for Disease Control and Prevention, 2021a). In Sweden, the PCC diagnosis code U09.9 was implemented comparatively early and has been in use since 16 October 2020 (National Board of Health and Welfare, 2021). The Swedish National Board of Health and Welfare recommends using the PCC diagnosis code to describe a symptom or condition that a physician assesses to be caused by a previous

COVID-19 infection. The recommendations do not specify how soon after the acute infection the PCC diagnosis should be applied.

In the present study, we utilised Swedish hospital data and primary healthcare data from the two largest regions in Sweden (Region Stockholm and Region Västra Götaland, 2.4 and 1.7 million inhabitants, respectively (Statistics Sweden, 2022)) to present the incidence rate and cumulative incidence of PCC overall and in different subgroups of COVID-19 patients, and to describe the characteristics of all adult COVID-19 patients with or without a PCC-diagnosis during the first 16 months of usage of the ICD-10 diagnosis code U09.9 in Sweden.

## Methods

### Data sources and study cohort

The Swedish Covid-19 Investigation for Future Insights – a Population Epidemiology Approach using Register Linkage (SCIFI-PEARL) project is a register-based cohort study in Sweden with a comprehensive database for the epidemiological study of COVID-19 in real-time (Nyberg et al., 2021). The present study is part of the SCIFI-PEARL research effort with a unique linkage of data collected from several Swedish national, regional, and quality registers. All citizens in Sweden are assigned a unique personal identity number at birth or at immigration that follows an individual throughout life. This enables us to include a near-complete study population with nearly 100% coverage of the healthcare system and a linkage between registers with extremely high accuracy (Ludvigsson et al., 2009). The registers included in the present study are the Longitudinal integrated database for health insurance and labour market studies (LISA), National Patient Register (NPR), Cause of Death Register (CDR), National Register of Notifiable Diseases (SmiNet), Swedish Intensive Care Register (SIR), National Diabetes Register (NDR), and the regional primary healthcare databases in Stockholm (VAL) and Västra Götaland (VEGA). The LISA database is held by Statistics Sweden and contains sociodemographic and socioeconomic data. The NPR and CDR are both held by the National Board of Health and Welfare; the former includes all inpatient and specialist outpatient healthcare in Sweden, and the latter includes all deaths in Sweden. The data from NPR includes patients regardless of a completed healthcare encounter or not. SmiNet is a register of all notifiable communicable diseases held by the Swedish Public Health Agency and includes all positive SARS-CoV-2 polymerase chain reaction (PCR) test results. In Sweden, SARS-CoV-2 PCR tests were mainly performed without inpatient, outpatient, or primary healthcare visits and positive test results have thus been

reported into SmiNet without registration of healthcare visits in NPR or VEGA/VAL (unless it occurred for a healthcare reason in which case a COVID-19 diagnosis code would be present to reflect the positive test and healthcare need). The VAL and VEGA databases comprise both public and most private primary healthcare in Region Stockholm and Region Västra Götaland (the largest and second-largest regions in Sweden). These two regions encompass approximately 4.1 million inhabitants, corresponding to nearly 40% of the Swedish population (Statistics Sweden, 2022). Although these regions include the two largest cities as well as the two largest university hospitals in Sweden, these regions also include rural areas. Since PCC to a large extent is diagnosed within primary healthcare in Sweden, the present study was limited to adult (≥18 years of age) residents in Region Stockholm and Västra Götaland at the study start date (31 January 2020), for whom we have information from all inpatient, specialist outpatient, and primary healthcare records (National Board of Health and Welfare, 2022). The university hospitals in these regions have advanced healthcare and serve as referral centers for other regions, however, we only included residents of these regions and not referred patients. Information from all registers was available until 15 February 2022. Inclusion criteria for this study included having a positive SARS-CoV-2 PCR test and/or a diagnosis of COVID-19 in any of the registers from the study start date 31 January 2020 until study end date 15 February 2022. Information on death and emigration was retrieved from CDR and LISA, respectively.

**Variables**

A COVID-19 case was defined as having the ICD-10 diagnosis COVID-19 (U07.1 or U07.2, as main or secondary diagnosis) in NPR/VEGA/VAL and/or having a positive SARS-CoV-2 PCR test result registered in SmiNet. The first registration of any of these (for discharge diagnosis

in the inpatient part of the NPR, admission date was used) was defined as the COVID-19 index date. PCC was defined as having the ICD-10 code U09.9 as the main or secondary diagnosis in NPR/VEGA/VAL, and the first occurrence of this code more than 28 days from the COVID-19 index date was defined as the PCC index date (Wanga et al., 2021). A PCC diagnosis within 28 days from the COVID-19 index date (without later PCC diagnoses in the same individual) was interpreted as a probable misclassification relating to the acute infection rather than prolonged symptoms. Follow-up was defined from the COVID-19 index date until the earliest of PCC index date, emigration, death, or end of the study. We required a minimum follow-up of 114 days (corresponding to the third quartile of follow-up between COVID-19 index date and PCC index date among PCC patients diagnosed after the introduction of the PCC diagnosis code) from COVID-19 index date until death, emigration, or end of the study. Between COVID-19 index date and PCC index date we required a minimum follow-up of 28 days.

In the acute phase of COVID-19, severity was categorised as either hospitalised (highest level of care: requiring intensive care or requiring non-intensive inpatient care), or not hospitalised (requiring neither intensive nor inpatient care). This categorisation was based on data from SIR and NPR's inpatient register.

Sociodemographic data such as age, residency, sex, country of birth, and education were obtained from the LISA database. Age was defined from birth until the start of the study, 31 January 2020, and categorised into five groups (18-34, 35-44, 45-54, 55-64, and ≥65 years of age). Countries of birth except for Sweden were aggregated to continental regions (categories: Sweden, Asia and Oceania, Africa, Europe except for Sweden, North and South

America, and unknown). Education was categorised into primary school level (<10 years), secondary school level (10-12 years), tertiary school level (>12 years), and unknown. Data on comorbidities were retrieved from NPR and NDR from 1 January 2015 until 31 December 2019. The comorbidities evaluated were broad definitions of respiratory disease (ICD-codes: J00-J99), cardiovascular disease (ICD-codes: I00-I99), and diabetes (ICD-codes: E10, E11). Data on medical diagnoses from healthcare encounters *after* the PCC index date (COVID-19 patients with PCC) or *after* 28 days from the COVID-19 index date (COVID-19 patients without PCC) were retrieved from the national inpatient and outpatient data in NPR and the regional primary healthcare data in VAL and VEGA, using both main and secondary diagnoses.

**Statistical analyses**

Characteristics of COVID-19 patients with or without PCC were analysed using descriptive statistics and presented as numbers (n), frequencies (%), median, interquartile range (IQR), cumulative incidence (calculated over the whole study period by dividing the number of PCC cases by the number of COVID-19 patients), and incidence rates (calculated by dividing the number of PCC cases by the sum of all COVID-19 cases' individual follow-up and expressed per 100 person-years). In analyses regarding cumulative incidence and incidence rate we used the whole follow-up as well as a truncated follow-up at 114 days to account for differences in length of follow-up across the study period. Mann-Whitney U test and Chi-square test were used to test for significance between groups.

To describe potential variant-specific characteristics, we stratified each patient's COVID-19 index date into distinct time periods corresponding to the dominant virus variant. In

Sweden, a combination of virus variants predominated from February 2020 to January 2021, followed by the alpha variant of concern (VOC) from February 2021 to June 2021, and the delta VOC from July 2021 to December 2021 (Public Health Agency, 2022a).

All analyses were performed using R Statistical Software (v4.1.3; R Core Team 2022).

**Sensitivity analyses**

Sensitivity analyses with both more and less restriction of the included population were conducted using i) all individuals diagnosed with PCC regardless of time between COVID-19 and PCC diagnosis (n=11,774) and ii) all individuals with PCC diagnosis requiring a minimum follow-up between the COVID-19 index date and the PCC index date of 90 days (n=7,375). The 2,040 PCC patients who had a PCC diagnosis but no preceding COVID-19 were not included in the main analyses. However, they are described in the supplemental material.

## Results

### Cumulative incidence and incidence rate of PCC

As of 15 February 2022, there were a total of 884,045 COVID-19 cases in the two largest regions in Sweden (Stockholm and Västra Götaland). Of these, 377,938 (42.8%) had a shorter follow-up until death, emigration, or end of the study than 114 days and were thus not included in the study (Supplemental Figure S1). Of the remaining cases, 11,774 individuals had a registered diagnosis of PCC at some time point (2.3%). When counting only individuals with a registered diagnosis of PCC after 28 days from their COVID-19 index date, 10,196 PCC cases remained (age range 18-101 years). Our results therefore show that 2.0 % of all COVID-19 cases in the two largest regions in Sweden have been diagnosed with PCC >28 days after their COVID-19 diagnosis, during the first 16 months of usage of the PCC diagnosis code.

When considering sex, 2.3% of all female COVID-19 cases were diagnosed with PCC, compared to 1.6% of all male COVID-19 cases. The age group 55-64 years had the highest proportion of diagnosed PCC among COVID-19 cases (3.5%), while the youngest age group (18-34 years) had the lowest proportion (0.8%). 1.7 PCC cases per 100 person-years among individuals born in Sweden was the lowest incidence rate across different regions of birth. Individuals with tertiary education had the highest incidence rate (2.0 cases per 100 person-years) across education levels. In general, the incidence rates showed a similar pattern as the results based on cumulative incidence (Table 1). When truncating the follow-up for all COVID-19 cases (with or without PCC) at 114 days, the patterns for cumulative incidence and incidence rate were similar to the analyses using full follow-up except for the virus variants (Supplementary Table S5).

Among COVID-19 patients with PCC, the median follow-up from COVID-19 index date until the PCC index date was 87 (IQR= 43-214) days. The median follow-up for COVID-19 patients without PCC was 403 (IQR=321-462) days (censored at death, emigration, or end of the study).

**PCC according to severity of COVID-19**

When stratifying COVID-19 cases (with and without PCC) by severity (hospitalised or non-hospitalised), most individuals had not been hospitalised for COVID-19 (with PCC n=7,162, without PCC n=471,079; Table 2 and Figure 1). The proportion of patients with PCC among patients having required intensive care for COVID-19 was 36.9% (COVID-19 cases with PCC n=926, COVID-19 cases without PCC n=1,583) from the start of the pandemic until the end of study 15 February 2022 (Table 1). The corresponding proportions among patients requiring non-intensive inpatient care and among non-hospitalised patients were 8.3% (with PCC n=2,108, without PCC n=23,249) and 1.5% (with PCC n=7,162, without PCC n=471,079), respectively.

Among non-hospitalised COVID-19 patients, patients with PCC were more likely women (69.9% vs 52.9%, p<0.001), older (median 47.1 years vs 41.4 years, p<0.001), with a tertiary education (51.0% vs 44.1%, p-value<0.001) and had a previous respiratory (14.3% vs 10.0%, p-value<0.001) or cardiovascular (11.0% vs 9.4%, p-value<0.001) disease compared to COVID-19 patients without PCC (Table 2).

In all three categories of COVID-19 severity, a majority were diagnosed with PCC within primary healthcare (Table 2). The median duration of intensive care among COVID-19

patients without PCC was 7 (IQR=3-14) days, and for patients with PCC it was 11 (IQR=5-24) days. For COVID-19 patients without PCC treated in non-intensive inpatient care (excluding the intensive care population), the median duration of care was 6 (IQR=3-10) days and with PCC 8 (IQR=4-12) days.

Overall, COVID-19 patients with PCC had a median of 7 (IQR=3-12) main and secondary diagnoses after their initial PCC diagnosis (Table 2). The most common diagnosis (COVID-19 diagnoses excluded) was malaise and fatigue (n=2,575) (Table 3a). For COVID-19 patients without PCC, the median was 4 (IQR=2-9) and the most common diagnosis was essential hypertension (n=65,940) (Table 3b).

**PCC according to specific time periods corresponding to dominant virus variants**

Next, using COVID-19 index dates, we grouped the COVID-19 patient population into distinct time periods corresponding to the dominant virus variant at the time of their infection to describe potential virus variant-specific characteristics (Figure 2 and Supplemental Figure S2). The cumulative incidence of PCC was lowest in the Delta VOC period (1.1% vs Mix of variants: 2.2% and Alpha VOC: 1.9%) (Table 1, Figure 2). However, the incidence rate of PCC was highest in the Delta VOC period (2.4 per 100 person-years vs Mix of variants: 1.7 and Alpha VOC: 2.2). The period corresponding to the Delta VOC had fewer diagnosed PCC cases than the other two periods (n=363 vs Mix of variants: n=6,277 and Alpha VOC: n=3,556), but had a shorter follow-up (Supplemental Table S1). When truncating the follow-up for all COVID-19 cases (with or without PCC) at 114 days, the Alpha VOC period had both the highest incidence rate (4.8 per 100 person-years vs Mix of variants: 3.1 and Delta VOC: 3.3)

and the highest cumulative incidence (1.5% vs Mix of variants: 1.0% and Delta VOC: 1.0%) (Supplemental Table S5).

**Sensitivity analyses**

In sensitivity analyses, the proportion of PCC cases to COVID-19 cases was 2.3% when including all PCC cases (n=11,774), and 1.5% when only including those fulfilling the 90 days restriction (n=7,375). The results regarding characteristics of these alternative study populations were quite similar (Supplemental Table S2). Most of the PCC cases had a positive SARS-CoV-2 PCR test (registered in SmiNet) before their PCC diagnosis 66.3% (n=8,114), 17.0% (n=2,082) had received a clinical diagnosis of COVID-19 without a positive PCR test and 16.7% (n=2,040) had neither a positive PCR test nor a diagnosis (Supplemental Table S3). In the two groups without a positive PCR test, the majority were diagnosed with PCC during the first half of 2021 and the group with diagnosis only had COVID-19 index dates largely during the first months of the pandemic (Supplemental Figures S3 and S4).

## Discussion

In the present study, we utilised Swedish hospital data and primary healthcare data from the two largest regions in Sweden (4.1 million inhabitants) to present the incidence rate, cumulative incidence, and describe characteristics of all adult patients receiving a PCC diagnosis during the first 16 months of usage of the ICD-10 diagnosis code U09.9 in Sweden. We show that 10,196 individuals, 2.0 % of all COVID-19 cases, had been diagnosed with PCC during the first 16 months of usage of the PCC diagnosis code. While the overall cumulative incidence was higher in patients with severe and critical COVID-19, most of the individuals diagnosed with PCC had not been hospitalised for COVID-19. This non-hospitalised group were more likely female, older, had tertiary education, and had a previous respiratory or cardiovascular disease compared to the COVID-19 patients without PCC.

A recent systematic review reported a range of PCC prevalence from 9% to 81% among 31 studies globally reporting PCC in widely varying selected COVID-19 study populations (Chen et al., 2022), and a recent umbrella review showed prevalences between 2% and 53% among different selected populations (Nittas et al., 2022). The differences in prevalence between studies seem to a large extent be due to differences in the study populations, follow-up time, the definition of post-COVID-19 condition (one or more symptoms after a certain amount of days after COVID-19), the accuracy of diagnosis, the reporting systems, and the capacity of healthcare systems (Crook et al., 2021). For example, a survey carried out by the Office for National Statistics in the UK showed that 9.9% of patients with COVID-19 reported at least one symptom 12 weeks after the COVID-19 index date (The Office for National Statistics, 2020). A cohort study from Wuhan (n=1,276), which interviewed patients about their symptoms and conducted physical examinations, laboratory tests, and a 6-minute

walking test after 6 and 12 months found that 49% of patients who previously had been hospitalised due to COVID-19 had at least one sequelae symptom 12 months after the initial infection (Huang L. et al., 2021). Assessment of PCC prevalence in truly population-based settings is rare in the previously published studies.

Since Sweden was early in implementing the U09.9 code, we chose to use this diagnosis code to describe the PCC prevalence as a reflection of actual clinical care and diagnosis-setting. There are however limitations to using U09.9 as a definition of PCC. In the Swedish National Board of Health and Welfare guidance, physicians are recommended to utilise the PCC code U09.9 when a symptom or condition is regarded as being caused by a previous COVID-19 infection. However, no instruction is given regarding how soon after the primary infection the code can be used. According to the case definition recently created by the WHO, PCC could be considered the first three months from COVID-19 onset, but four weeks have also been used as a definition in earlier studies (Wanga et al., 2021). Therefore, in our main analyses we did not define 1,578 patients as PCC cases since they were only given the PCC code within 28 days after the COVID-19 index date (and not again). Possible explanations for a PCC diagnosis within 28 days of COVID-19 index date include patients not getting tested for SARS-CoV-2 during the acute infection and then receiving a late COVID-19 diagnosis when seeking healthcare for PCC symptoms (early during the pandemic the testing capacity in Sweden was very low), or misclassification as there was no specification in Sweden on how soon after COVID-19 a PCC diagnosis could be used, or that acute COVID-19 symptoms were misclassified as PCC. It is also difficult to distinguish between PCC and other possible effects of hospitalisation and intensive care treatment. This issue is not overcome by using the U09.9 code, and we are therefore unable to discriminate between these

conditions in our study. Furthermore, partly due to the wide definition of PCC and the lack of knowledge about the condition, it is likely that not all patients experiencing post-COVID-19 complications are diagnosed with PCC and receive the U09.9 code (Walker et al., 2021). In Sweden, the Public Health Agency recommended the same public health surveillance for COVID-19 in all regions, although a recent report concluded that Region Stockholm and Västra Götaland had lower test capacity than other regions, especially during 2020 (Almgren and Björk, 2021). Lastly, the diagnosis code has not yet been validated in a Swedish setting. Therefore, the true cumulative incidence of PCC could both be higher and lower than our estimate. Increased usage of the WHO-implemented ICD-10 code U09.9 in future studies can hopefully assist in making comparisons between studies, even though many complicating factors will remain.

When considering prevalence data on PCC in different settings and populations, it is important to be aware of the limitations present in the various reports. The Swedish National Board of Health and Welfare regularly presents nationwide data on the PCC prevalence in Sweden, although their results are based on aggregated primary healthcare data. Their latest report estimated that 16,019 individuals received a PCC diagnosis within the public primary healthcare from October 2020 until October 2021 in the whole of Sweden (National Board of Health and Welfare, 2022). Additionally, in the report, data from the NPR showed that 5,710 individuals received a PCC diagnosis in a hospital or outpatient clinic during the same period (National Board of Health and Welfare, 2022). However, the use of aggregated primary healthcare data, thus not individual-level data, makes it likely that there is some overlap between data from primary care and hospital/outpatient care. Furthermore, data are gathered from primary care within the public health system only, while numbers

regarding private primary care are based on estimates. By having access to individual data from NPR as well as from both public and private primary healthcare, our results regarding the cumulative incidence of PCC in the two largest regions in Sweden are likely more accurate than the Swedish governmental reports. The fact that the majority of PCC patients in our study were diagnosed within primary healthcare (88.6%), further emphasises the importance of having individual-based data from primary healthcare.

Our results showed a clear difference in cumulative incidence of PCC depending on the severity of the primary infection. Among patients having required intensive care for COVID-19, 36.9 % went on to receive a PCC diagnosis, while the proportion of PCC diagnoses among non-hospitalised patients was only 1.5%. This is in line with previous reports showing a possible association between more severe acute infection and increased risk of developing PCC (Huang L. et al., 2021, Sudre et al., 2021). Furthermore, the high numbers of PCC among patients requiring intensive care for COVID-19 likely include patients suffering the consequences of hospital care, including the so-called post-intensive care syndrome (Rawal et al., 2017). Consistent with previous reports (Augustin et al., 2021, Huang C. et al., 2021, National Board of Health and Welfare, 2022), we also showed that females were more likely to receive a PCC diagnosis than men: 2.3% and 1.6%, respectively. There was also a difference across age groups, and the highest proportions of PCC were seen at ages 55-64 years. Different health-seeking behaviours between the sexes as well as between different age groups might explain some of these differences in PCC prevalence, both in terms of getting tested for SARS-CoV-2 during the initial infection and in seeking healthcare when experiencing symptoms of PCC (Thompson et al., 2016). Furthermore, patients initially hospitalised for COVID-19 might be more prone to continue seeking medical care after

hospitalisation, and there might also be different patterns of health-seeking behaviour in the other subgroups evaluated in this study. One inevitable limitation to diagnosis-based register studies such as the present study is that these types of health-seeking behaviour differences across subgroups might introduce self-selection bias. Nevertheless, the results presented here will be relevant and useful for assessing the future impact of PCC on healthcare, as a reflection of real-world healthcare practices.

It is still unclear whether different SARS-CoV-2 variants have the same potential to cause sequelae symptoms and PCC after the initial infection and if there are any virus variant-specific characterisations of the condition. The present study shows that the cumulative incidence was lower in the Delta VOC period compared to the other periods, but the incidence rate was higher. This might be due to the shorter follow-up in the Delta VOC period and considering that the study end date was 15 February 2022 and that we required a minimum follow-up of 114 days, individuals whose COVID-19 index date was closer to the end of the study had less time to develop PCC. Hence, the results regarding PCC among patients infected by SARS-CoV-2 when the delta VOC was dominant (n=363) in Sweden (July 2021 until December 2021) must be interpreted cautiously. When accounting for differences in length of follow-up by using a truncated follow-up, we show that the Alpha VOC period had a higher incidence rate and cumulative incidence compared to the other two periods. PCR confirmation of COVID-19 (84.6%) was comparatively low early in the period when a mix of virus strains was circulating, due to the limited test capacity in Sweden during the first months of the pandemic.

Early in the pandemic, Sweden chose an approach to mitigate the pandemic that was different from most other countries, including the Nordic countries. The strategy was based on voluntary measures and personal responsibility of the Swedish population (Ludvigsson, 2022). A commission concluded in 2022 that although the overall mortality (2020-2021) was lower than in many other countries, earlier and more extensive measures should have been undertaken early on during the pandemic (Ludvigsson, 2022). Vaccination of individuals in risk groups started in late 2020 and early 2021 and continued on a large scale for the whole adult population in the second quarter of 2021 (Public Health Agency, 2022b). In the middle of the summer 2021, around 70% of the population had taken their first dose, meaning that the risk of severe COVID-19 had changed by the end of the study period.

Our study has several strengths: it is population-based and includes a near-complete data set from inpatient, outpatient, and primary healthcare data. Moreover, we use individual-level data and can thus distinguish individuals appearing in more than one register and avoid data duplication or overlap. Importantly, we include data from both public and private primary healthcare.

In conclusion, we present data on the estimated cumulative incidence of PCC in a truly population-based setting in the two largest regions in Sweden, together with a detailed characterisation of the patient population diagnosed with PCC during the first 16 months of usage of the ICD-10 diagnosis code U09.9. This knowledge is important to further the understanding of this emerging patient group. However, more research is urgently needed to improve diagnosis and clinical care for these patients.

## Contributorship statement

The work described in this article was conceptualized and designed by MB, SL, and FN. All authors made substantial contributions to the acquisition (AS, HL, MG, FN), analysis (MB, JM, HL), or interpretation (MB, SL, LL, DG, JM, AS, HL, MG, FN) of data for the work. MB, SL, and LL drafted the manuscript, all authors revised it critically for important intellectual content and gave their final approval of the version to be published and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. MB and FN directly accessed and verified the underlying data reported in the manuscript. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

## Ethical approval

The Swedish Ethical Review Authority approved the study (Dnr: 2020-01800).

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interpretation of data; in the writing of the report; and in the decision to submit the article for publication.

## Conflict of interest

All authors have completed Conflicts of interest statements forms (available on request from the corresponding author) and declare: MB has funding by research grants from Svenska sällskapet för Medicinsk Forskning (SSMF), Swedish Research Council for Health, Working Life, and Welfare (FORTE), and Mary von Sydow's foundation; SL has funding by a Swedish government research grant through the ALF-agreement; MG has funding by a Swedish government research grant through the ALF-agreement and from FORMAS, Swedish Research Council for Sustainable Development; MG has received personal honoraria from Amgen, Biogen, BMS, Gilead, GSK/ViiV, Janssen-Cilag, MSD, Novocure, and Novo Nordic and participated on a scientific advisory board for Astra Zeneca (DSMB), Gilead, GSK/ViiV, Pfizer, and MSD; FN has funding for the submitted work by a Swedish government research grant through the ALF-agreement and from FORMAS, Swedish Research Council for Sustainable Development; FN has funding via research grants from the Swedish Research Council, Swedish Heart-lung foundation, SciLifeLab / Knut & Alice Wallenberg Foundation, and Swedish Social Insurance Agency; FN had a prior employment at Astra Zeneca until 2019, and owns some Astra Zeneca shares; no other relationships or activities that could appear to have influenced the submitted work.

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## Figure legends

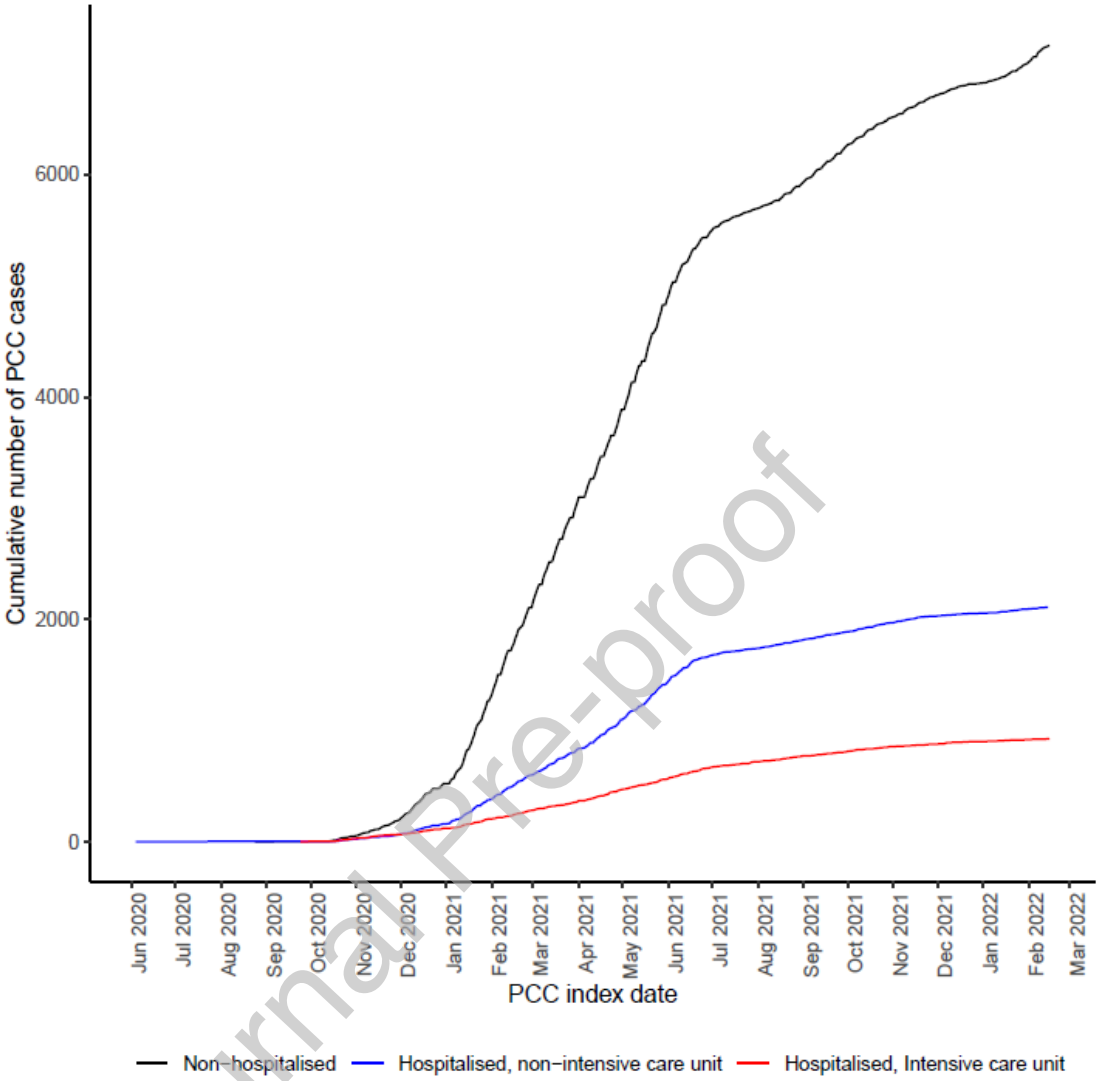


**Figure 1.** The cumulative number of post-COVID-19 condition (PCC) cases until 15 February 2022 according to COVID-19 severity. Study population from the two largest regions in Sweden, Stockholm and Västra Götaland, including both primary healthcare data and inpatient/outpatient specialist healthcare data.

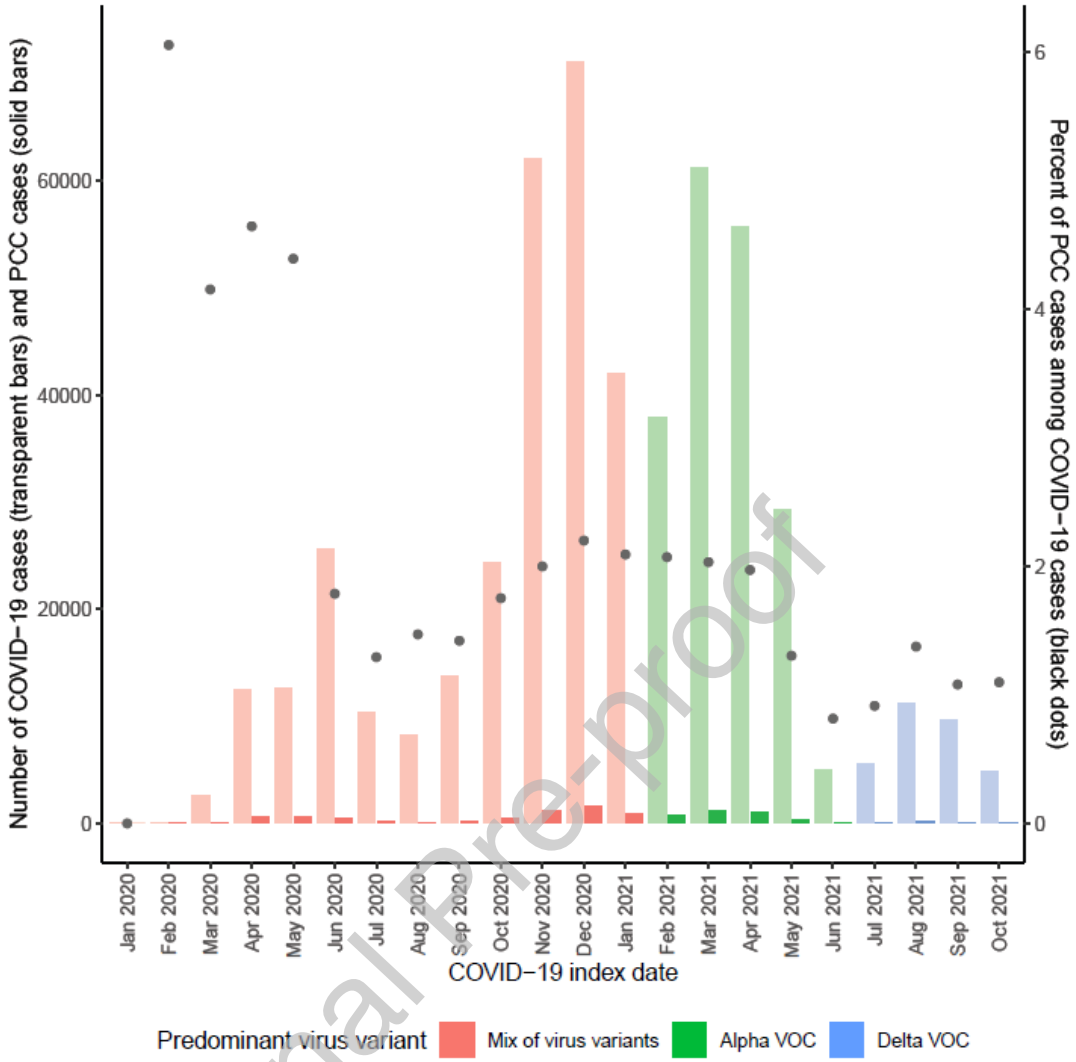


**Figure 2.** On the left y-axis: bar plot of COVID-19 cases (transparent colour) and post-COVID-19 condition (PCC) cases (full colour) according to COVID-19 index date (month and year). On the right y-axis: the percentage of PCC cases among COVID-19 cases (black dots). Study population from the two largest regions in Sweden, Stockholm and Västra Götaland, including both primary healthcare data and inpatient/outpatient specialist healthcare data, until 15 February 2022. Specific time periods of predominant virus variant of concern (VOC) indicated. Early during the pandemic, the PCR testing was very low in Sweden which is reflected in the low incidence of COVID-19 cases. A zoom in on the PCC cases is available in Supplemental Figure S2.

**Table 1.** Incidence rate and cumulative incidence for post-COVID-19 condition (PCC) diagnosis among COVID-19 cases stratified according to the initial care requirement for COVID-19. COVID-19 cases from the two largest regions in Sweden, Stockholm and Västra Götaland, including both primary healthcare data and inpatient/outpatient specialist healthcare data, until 15 February 2022.

[1]Age on study start 31 January 2020.

| | Incidence rate (per 100 person-years) | | | | Cumulative incidence (%) | | | |
|---|---|---|---|---|---|---|---|---|
| **Acute COVID-19 care level** | **Non-hospitalised** | **Hospitalised, non-intensive care unit** | **Hospitalised, Intensive care unit** | **Overall** | **Non-hospitalised** | **Hospitalised, non-intensive care unit** | **Hospitalised, Intensive care unit** | **Overall** |
| Overall | 1.4 | 7.1 | 36.5 | 1.8 | 1.5 | 8.3 | 36.9 | 2.0 |
| Sex | | | | | | | | |
| Men | 0.9 | 6.9 | 34.8 | 1.5 | 1.0 | 8.0 | 35.9 | 1.6 |
| Women | 1.8 | 7.4 | 40.8 | 2.1 | 2.0 | 8.7 | 39.2 | 2.3 |
| Age group[1] (years) | | | | | | | | |
| 18-34 | 0.7 | 2.9 | 18.3 | 0.8 | 0.8 | 3.5 | 20.9 | 0.8 |
| 35-44 | 1.6 | 8.0 | 46.0 | 1.9 | 1.7 | 9.3 | 41.0 | 2.0 |
| 45-54 | 2.0 | 10.8 | 42.6 | 2.6 | 2.2 | 12.5 | 43.4 | 2.8 |
| 55-64 | 2.1 | 10.5 | 40.4 | 3.1 | 2.3 | 12.2 | 40.9 | 3.5 |
| ≥65 | 0.9 | 5.0 | 31.0 | 2.2 | 1.0 | 5.9 | 31.3 | 2.5 |
| Region of birth | | | | | | | | |
| Africa | 1.0 | 6.0 | 31.1 | 1.8 | 1.1 | 7.4 | 35.9 | 2.0 |
| Asia and Oceania | 1.5 | 6.8 | 34.4 | 2.2 | 1.6 | 8.1 | 36.2 | 2.3 |
| Europe[2] | 1.6 | 7.3 | 37.8 | 2.5 | 1.7 | 8.7 | 37.6 | 2.7 |
| North and South America | 1.9 | 8.3 | 39.5 | 2.8 | 2.1 | 10.1 | 41.7 | 3.0 |
| Sweden | 1.3 | 7.1 | 36.7 | 1.7 | 1.4 | 8.2 | 36.2 | 1.8 |
| Unknown | 1.8 | 8.2 | 47.2 | 2.4 | 1.9 | 9.3 | 43.0 | 2.5 |
| Education | | | | | | | | |
| Primary school | 1.0 | 4.8 | 31.2 | 1.6 | 1.0 | 5.7 | 31.6 | 1.8 |
| Secondary school | 1.3 | 7.8 | 39.5 | 1.8 | 1.4 | 9.1 | 39.3 | 2.0 |
| Tertiary school | 1.6 | 8.4 | 38.0 | 2.0 | 1.7 | 9.7 | 39.0 | 2.1 |
| Unknown | 0.6 | 3.8 | 26.4 | 1.1 | 0.6 | 4.6 | 28.0 | 1.2 |
| Virus variant[3] | | | | | | | | |
| Mix of virus variants | 1.3 | 4.7 | 27.1 | 1.7 | 1.7 | 6.6 | 33.3 | 2.2 |
| Alpha VOC | 1.5 | 15.7 | 76.0 | 2.2 | 1.3 | 12.4 | 45.2 | 1.9 |
| Delta VOC | 1.5 | 20.5 | 114.7 | 2.4 | 0.7 | 8.7 | 39.6 | 1.1 |

[2]Not including Sweden.

[3]Virus variants corresponding to specific time periods. In Sweden, a combination of virus variants predominated from February 2020 to January 2021, followed by the alpha variant of concern (VOC) from February 2021 to June 2021, and the delta VOC from July 2021 to December 2021

**Table 2.** Descriptive statistics for COVID-19 cases with or without post-COVID-19 condition (PCC) diagnosis in the two largest regions in Sweden, Stockholm and Västra Götaland, including both primary healthcare data and inpatient/outpatient specialist healthcare data, until 15 February 2022. Stratified according to the initial care requirement for COVID-19.

| Acute COVID-19 care level | Non-hospitalised | | | Hospitalised, non-intensive care unit | | | Hospitalised, intensive care unit | | | All | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | COVID-19 cases without PCC | COVID-19 cases with PCC | p-value | COVID-19 cases without PCC | COVID-19 cases with PCC | p-value | COVID-19 cases without PCC | COVID-19 cases with PCC | p-value | COVID-19 cases without PCC | COVID-19 cases with PCC | p-value |
| Total, n | 471,079 | 7,162 | | 23,249 | 2,108 | | 1,583 | 926 | | 495,911 | 10,196 | |
| Sex, n (%) | | | <0.001 | | | 0.066 | | | 0.129 | | | <0.001 |
| Men | 221,905 (47.1) | 2,158 (30.1) | | 12,799 (55.1) | 1,116 (52.9) | | 1,124 (71.0) | 630 (68.0) | | 235,828 (47.6) | 3,904 (38.3) | |
| Women | 249,174 (52.9) | 5,004 (69.9) | | 10,450 (44.9) | 992 (47.1) | | 459 (29.0) | 296 (32.0) | | 260,083 (52.4) | 6,292 (61.7) | |
| Age[1] (years), median (IQR) | 41.4 (30.2-53.3) | 47.1 (38.2-55.4) | <0.001 | 62.8 (48.6-76.3) | 58.2 (49.1-69.0) | <0.001 | 60.2 (49.8-68.2) | 58.3 (50.0-65.9) | 0.028 | 42.2 (30.7-54.5) | 50.3 (40.9-59.1) | <0.001 |
| Age group[1] (years), n (%) | | | <0.001 | | | <0.001 | | | <0.001 | | | <0.001 |
| 18-34 | 170,635 (36.2) | 1,325 (18.5) | | 2,327 (10.0) | 84 (4.0) | | 140 (8.8) | 37 (4.0) | | 173,102 (34.9) | 1,446 (14.2) | |
| 35-44 | 101,371 (21.5) | 1,782 (24.9) | | 2,362 (10.2) | 243 (11.5) | | 138 (8.7) | 96 (10.4) | | 103,871 (20.9) | 2,121 (20.8) | |
| 45-54 | 96,420 (20.5) | 2,185 (30.5) | | 3,655 (15.7) | 520 (24.7) | | 292 (18.4) | 224 (24.2) | | 100,367 (20.2) | 2,929 (28.7) | |
| 55-64 | 61,233 (13.0) | 1,453 (20.3) | | 4,275 (18.4) | 596 (28.3) | | 457 (28.9) | 316 (34.1) | | 65,965 (13.3) | 2,365 (23.2) | |
| ≥65 | 41,420 (8.8) | 417 (5.8) | | 10,630 (45.7) | 665 (31.5) | | 556 (35.1) | 253 (27.3) | | 52,606 (10.6) | 1,335 (13.1) | |
| Region of birth, n (%) | | | <0.001 | | | 0.189 | | | 0.643 | | | <0.001 |
| Africa | 12,653 (2.7) | 138 (1.9) | | 1,057 (4.5) | 85 (4.0) | | 100 (6.3) | 56 (6.0) | | 13,810 (2.8) | 279 (2.7) | |
| Asia and Oceania | 54,199 (11.5) | 859 (12.0) | | 4,095 (17.6) | 359 (17.0) | | 316 (20.0) | 179 (19.3) | | 58,610 (11.8) | 1,397 (13.7) | |
| Europe[2] | 29,041 (6.2) | 498 (7.0) | | 2,573 (11.1) | 245 (11.6) | | 221 (14.0) | 133 (14.4) | | 31,835 (6.4) | 876 (8.6) | |
| North and South America | 9,790 (2.1) | 211 (2.9) | | 720 (3.1) | 81 (3.8) | | 56 (3.5) | 40 (4.3) | | 10,566 (2.1) | 332 (3.3) | |
| Sweden | 346,397 (73.5) | 5,095 (71.1) | | 13,711 (59.0) | 1,225 (58.1) | | 821 (51.9) | 466 (50.3) | | 360,929 (72.8) | 6,786 (66.6) | |
| Unknown | 18,999 (4.0) | 361 (5.0) | | 1,093 (4.7) | 113 (5.4) | | 69 (4.4) | 52 (5.6) | | 20,161 (4.1) | 526 (5.2) | |
| Education, n (%) | | | <0.001 | | | <0.001 | | | 0.002 | | | <0.001 |
| Primary school | 60,615 (12.9) | 642 (9.0) | | 5,862 (25.2) | 357 (16.9) | | 435 (27.5) | 201 (21.7) | | 66,912 (13.5) | 1,200 (11.8) | |
| Secondary school | 194,038 (41.2) | 2,815 (39.3) | | 9,164 (39.4) | 915 (43.4) | | 663 (41.9) | 430 (46.4) | | 203,865 (41.1) | 4,160 (40.8) | |
| Tertiary school | 207,551 (44.1) | 3,653 (51.0) | | 7,382 (31.8) | 795 (37.7) | | 426 (26.9) | 272 (29.4) | | 215,359 (43.4) | 4,720 (46.3) | |
| Unknown | 8,875 (1.9) | 52 (0.7) | | 841 (3.6) | 41 (1.9) | | 59 (3.7) | 23 (2.5) | | 9,775 (2.0) | 116 (1.1) | |
| Comorbidities, n (%) | | | | | | | | | | | | |
| Respiratory disease | 47,103 (10.0) | 1,027 (14.3) | <0.001 | 5,344 (23.0) | 487 (23.1) | 0.925 | 285 (18.0) | 183 (19.8) | 0.299 | 52,732 (10.6) | 1697 (16.6) | <0.001 |
| No respiratory disease | 423,976 (90.0) | 6,135 (85.7) | | 17,905 (77.0) | 1,621 (76.9) | | 1,298 (82.0) | 743 (80.2) | | 443,179 (89.4) | 8,499 (83.4) | |
| Cardiovascular disease | 44,440 (9.4) | 787 (11.0) | <0.001 | 8,631 (37.1) | 622 (29.5) | <0.001 | 455 (28.7) | 242 (26.1) | 0.173 | 53,526 (10.8) | 1,651 (16.2) | <0.001 |
| No cardiovascular disease | 426,639 (90.6) | 6,375 (89.0) | | 14,618 (62.9) | 1,486 (70.5) | | 1,128 (71.3) | 684 (73.9) | | 442,385 (89.2) | 8,545 (83.8) | |
| Diabetes | 19,026 (4.0) | 298 (4.2) | 0.624 | 4,552 (19.6) | 366 (17.4) | 0.015 | 370 (23.4) | 196 (21.2) | 0.220 | 23,948 (4.8) | 860 (8.4) | <0.001 |
| No diabetes | 452,053 (96.0) | 6,864 (95.8) | | 18,697 (80.4) | 1,742 (82.6) | | 1,213 (76.6) | 730 (78.8) | | 471,963 (95.2) | 9,336 (91.6) | |
| Source of COVID-19 classification, n (%) | | | 0.053 | | | <0.001 | | | 0.007 | | | <0.001 |
| Positive PCR test[3] | 337,302 (71.6) | 5,203 (72.6) | | 20,658 (88.9) | 2,008 (95.3) | | 1,508 (95.3) | 903 (97.5) | | 359,468 (72.5) | 8,114 (79.6) | |
| Diagnosis only, no positive PCR test[4] | 133,777 (28.4) | 1,959 (27.4) | | 2,591 (11.1) | 100 (4.7) | | 75 (4.7) | 23 (2.5) | | 136,443 (27.5) | 2,082 (20.4) | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Number of diagnoses[5], median (IQR) | 4 (2-8) | 6 (3-10) | | 13 (7-22) | 9 (4-15) | | 17 (11-25) | 11 (6-16) | | 4 (2-9) | 7 (3-12) |
| Follow-up (days), median (IQR) | 400 (321-460) | 94 (43-220) | | 432 (333-626) | 61 (38-167) | | 457 (343-657) | 118 (57-247) | | 403 (321-462) | 87 (43-214) |
| First PCC diagnosis from, n (%) | | | | | | | | | | | |
| Inpatient care | | 138 (1.9) | | | 199 (9.4) | | | 159 (17.2) | | | 496 (4.9) |
| Outpatient care | | 289 (4.0) | | | 151 (7.2) | | | 222 (24.0) | | | 662 (6.5) |
| Primary care | | 6,735 (94.0) | | | 1,758 (83.4) | | | 545 (58.9) | | | 9,038 (88.6) |

We required a minimum follow-up from COVID-19 index date until death, emigration, or end of study of 114 days. We required a minimum follow-up between COVID-19 index date and PCC index date of 28 days.

[1]Age on study start 31 January 2020.

[2]Not including Sweden.

[3]From SmiNet, first positive test before PCC diagnosis.

[4]Among PCC cases: n specialist care= 231, n primary care= 1,851. Among COVID-19 cases: n specialist care= 6,651, n primary care= 129,792.

[5]Main and secondary diagnoses after PCC index date or 28 days after COVID-19 index date.

PCR=Polymerase Chain Reaction, IQR=Interquartile Range

**Table 3a.** Number (%) of COVID-19 cases with post-COVID-19 condition (PCC) diagnosed with the most common diagnoses (main and secondary) after PCC index date, stratified according to the initial care requirement for COVID-19. Study population from the two largest regions in Sweden, Stockholm and Västra Götaland, including both primary healthcare data and inpatient/outpatient specialist healthcare data, until 15 February 2022.

| | **COVID-19 cases with PCC** | | | |
|---|---|---|---|---|
| **Acute COVID-19 care level/ Diagnoses after PCC** | **Non-hospitalised** (n=7,162) | **Hospitalised, non-intensive care unit** (n=2,108) | **Hospitalised, intensive care unit** (n=926) | **All** (n=10,196) |
| **R53.9** Malaise and fatigue | 1,963 (27.4) | 428 (20.3) | 184 (19.9) | 2,575 (25.3) |
| **I10.9** Essential hypertension | 1,132 (15.8) | 768 (36.4) | 441 (47.6) | 2,341 (23.0) |
| **R06.0** Dyspnoea | 1,254 (17.5) | 513 (24.3) | 339 (36.6) | 2,106 (20.7) |
| **R52.9** Pain, unspecified | 1,299 (18.1) | 366 (17.4) | 183 (19.8) | 1,848 (18.1) |
| **R05.9** Cough, unspecified | 805 (11.2) | 237 (11.2) | 134 (14.5) | 1,176 (11.5) |
| **G93.3** Postviral fatigue syndrome | 919 (12.8) | 145 (6.9) | 76 (8.2) | 1,140 (11.2) |
| **J45.9** Unspecified asthma | 631 (8.8) | 272 (12.9) | 112 (12.1) | 1,015 (10.0) |
| **R51.9** Headache, unspecified | 821 (11.5) | 130 (6.2) | 50 (5.4) | 1,001 (9.8) |
| **G47.9** Sleep disorder, unspecified | 633 (8.8) | 198 (9.4) | 95 (10.3) | 926 (9.1) |
| **E11.9** Type 2 Diabetes Mellitus without complications | 301 (4.2) | 366 (17.4) | 236 (25.5) | 903 (8.9) |

Diagnoses from the U-chapter excluded.

**Table 3b.** Number (%) of COVID-19 cases without post-COVID-19 condition (PCC) diagnosed with the most common diagnoses (main and secondary) more than 28 days after COVID-19 index date, stratified according to the initial care requirement for COVID-19. Study population from the two largest regions in Sweden, Stockholm and Västra Götaland, including both primary healthcare data and inpatient/outpatient specialist healthcare data, until 15 February 2022.

| | **COVID-19 cases without PCC** | | | |
|---|---|---|---|---|
| **Acute COVID-19 care level/ Diagnoses after COVID-19**[1] | **Non-hospitalised** (n=471,079) | **Hospitalised, non-intensive care unit** (n=23,249) | **Hospitalised, intensive care unit** (n=1,583) | **All** (n=495,911) |
| **I10.9** Essential hypertension | 53,910 (11.4) | 11,166 (48.0) | 864 (54.6) | 65,940 (13.3) |
| **R52.9** Pain, unspecified | 61,056 (13.0) | 4,060 (17.5) | 265 (16.7) | 65,381 (13.2) |
| **R53.9** Malaise and fatigue | 36,047 (7.7) | 3,688 (15.9) | 274 (17.3) | 40,009 (8.1) |
| **R05.9** Cough, unspecified | 35,254 (7.5) | 4,106 (17.7) | 356 (22.5) | 39,716 (8.0) |
| **J06.9** Acute upper respiratory infection, unspecified | 32,453 (6.9) | 1,720 (7.4) | 113 (7.1) | 34,286 (6.9) |
| **R10.4X** Abdominal pain, unspecified | 29,238 (6.2) | 2,875 (12.4) | 157 (9.9) | 32,270 (6.5) |
| **F41.9** Anxiety disorder, unspecified | 23,855 (5.1) | 1,399 (6.0) | 78 (4.9) | 25,332 (5.1) |
| **R06.0** Dyspnoea | 16,743 (3.6) | 7,578 (32.6) | 758 (47.9) | 25,079 (5.1) |
| **G47.9** Sleep disorder, unspecified | 21,337 (4.5) | 2,003 (8.6) | 162 (10.2) | 23,502 (4.7) |
| **R51.9** Headache, unspecified | 20,888 (4.4) | 1,341 (5.8) | 75 (4.7) | 22,304 (4.5) |

Diagnoses from the U-chapter excluded.

[1]Diagnoses from healthcare visits from day 29 after COVID-19 index date until end of follow-up.